3. DEVELOPMENT AND SCREENING OF ALTERNATIVES

This section presents initial development and screening of a series of remedial action alternatives that span the GRAs and address the identified WAG 7 RAOs. Alternatives were assembled from technologies and process options retained after evaluations presented in Section 2. This initial alternative screening process was conducted to identify the most appropriate remedial action alternatives to be retained for a more detailed analysis in accordance with CERCLA (42 USC § 9601 et seq.) feasibility study guidelines. More detailed analysis of retained alternatives is presented in Section 4 of this report.

For this initial screening analysis, seven remedial action alternatives were assembled to facilitate general comparative assessments and provide a perspective for implementing each of the GRAs. Assembled alternatives, with their primary technology applications, are summarized in Figure 3-1.

- A No Action alternative—Provides a basis for comparative analyses in accordance with CERCLA guidance. This alternative includes an environmental monitoring component to facilitate future assessments of site impacts.

- A Limited Action alternative—Relies on site access controls, a surface barrier, and land-use restrictions to protect human health.

- Two containment alternatives—Rely primarily on constructing surface and subsurface barriers to prevent access to waste and control future contaminant migration.

- Two in situ treatment alternatives—Focus on applying either ISV or ISG technology to treat and stabilize waste and contaminated soil in place.

- A Retrieval, Treatment, and Disposal (RTD) alternative—Focuses on retrieving and treating waste and contaminated soil with off-Site disposal of TRU material and onsite disposal of LLW and treated MLLW material.

Figure 3-1. Remedial action alternatives.

As shown in Figure 3-1, the alternatives comprise a number of common technology applications. All of the alternatives include a monitoring component and, except for the No Action alternative, require implementing institutional controls and placement of a cap to prevent future access to waste. Alternatives primarily differ in approach to stabilizing and treating RFP TRU waste streams, which contain the majority of the actinide-, VOC-, and nitrate-bearing waste. Each alternative features a primary technology (containment, ISG, ISV, or RTD) to remediate these waste streams. However, it should be noted that in considering either technology limitations or pretreatment requirements, supplemental technologies have been included in the alternatives to address site-specific needs. Remediation of non-RFP waste streams containing groundwater COCs also is addressed in each alternative either through applying primary or supplemental technologies.

In following sections, preliminary remedial alternatives are described and screened, either individually or by GRA, to identify candidate remedial alternatives. Remaining alternatives will undergo a more detailed analysis and comparative evaluation in Section 4, in accordance with CERCLA feasibility study evaluation criteria. Alternatives presented in this chapter incorporate representative technologies and process options, identified and screened in Section 2, to provide a comparative assessment of effectiveness, implementability, and cost.

3.1   Scope of Remedial Action

The primary focus of this analysis is to identify and evaluate remedial alternatives that address potential human health and ecological risks associated with buried waste (source term) within the SDA. Alternatives are structured to focus specific technologies on mitigating risks resulting from identified COCs. Scope of required remedial measures is based on available waste inventory data, which identify extent and location of waste streams in the SDA that contain the primary COCs. Distribution of these contaminants was presented in the ABRA (Holdren et al. 2002) and is summarized in Section 2 of this report.

Given the general distribution of the COCs and level of health risks identified in the ABRA, alternatives developed for this analysis were structured to address all the COC-bearing waste streams within the SDA. Alternatives focusing on hot spot treatment or retrieval actions could not be developed to a level that would achieve the required risk reduction needed for conformance with project RAOs. As noted in the ABRA, waste containing identified COCs is widely distributed in disposal sites within the SDA. The actinide COCs (i.e., americium, uranium, neptunium, and plutonium) are distributed primarily in the RFP waste located in Pits 1 through 6 and 9 through 12, Trenches 1 through 10, and Pad A. These disposal sites also contain the nitrate- and VOC-bearing COC waste. Activation and fission product COCs are primarily located in the SVRs and the remaining trench areas, though some also have been disposed of in Pits 8, 9, and 10.

As discussed in the preceding section, in addition to the No Action and the Limited Action alternatives, two containment alternatives, two in situ treatment alternatives (ISV and ISG), and one RTD alternative were developed for this initial screening. The first two alternatives involve remedial actions that address the SDA on the whole, and are not focused on preventing or reducing future contaminant migration and do not stabilize or treat specific groundwater COCs within buried waste. As such, these two alternatives are not burial-site-specific (i.e., applicable to individual pits or trenches). However, for the remaining alternatives, including the containment alternatives, the in situ treatment alternatives (ISG and ISV), and the RTD alternative, site-specific applications of individual technologies are considered to address groundwater risk associated with both TRU and non-TRU waste.

3.1.1 Rocky Flats Plant Waste Locations

To provide a comparative perspective for this PERA, alternatives will apply specific in situ treatment and retrieval technologies on burial sites containing TRU waste received from the RFP. Available inventory data indicate that the following disposal units contain these types of waste.

- Pits 1 through 6 and 9 through 12

- Trenches 1 through 10

- Pad A.

As shown in contaminant distribution maps presented in the ABRA (Holdren et al. 2002), waste streams associated with RFP waste contain the majority of actinides (e.g., plutonium, uranium, americium, and neptunium), nitrates, and VOCs (e.g., CCl_4, PCE, and methylene chloride). General locations of these burial sites along with the distribution of actinide-, VOC-, and nitrate-bearing streams are shown on Figure 3-2.
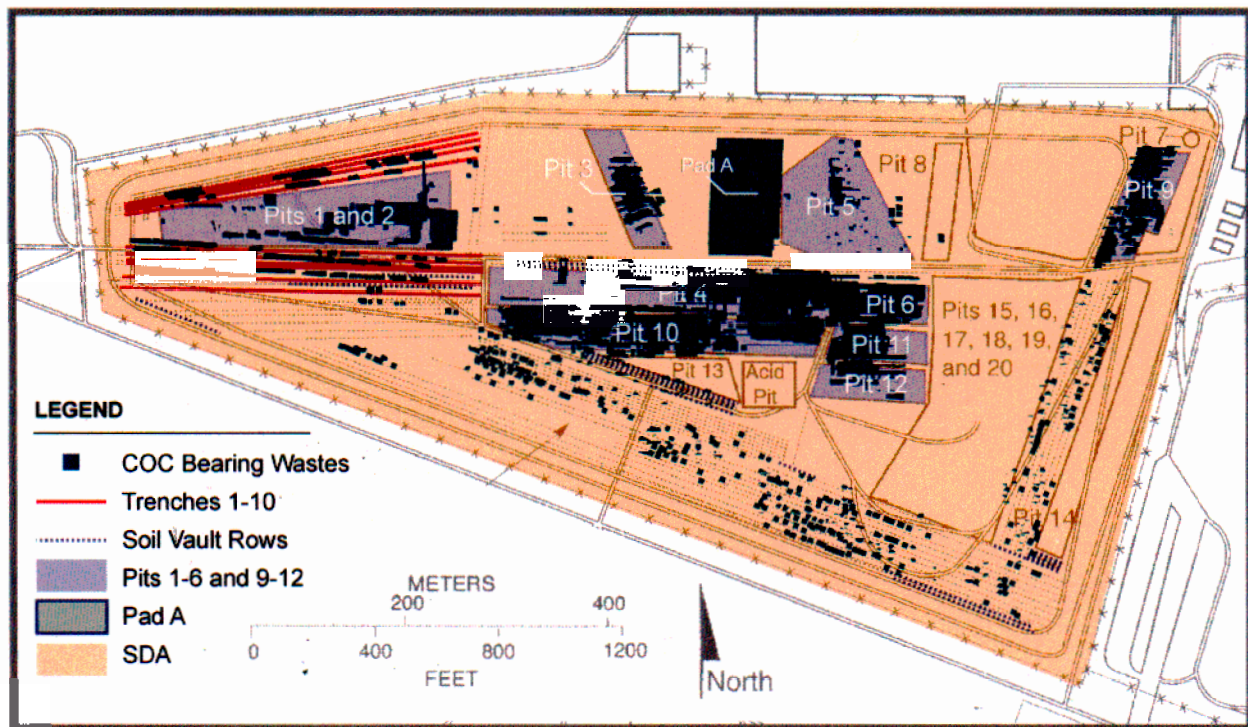

Figure 3-2. Selected waste disposal units at the Radioactive Waste Management Complex.

Based upon available disposal records and inventory data, areas within disposal units containing higher and lower concentrations of COC-bearing waste can be identified. However, for the purpose of this analysis, it is assumed that applying in situ treatment and retrieval technologies that target the RFP waste would address each disposal unit as a whole (i.e., the full extent of each pit and trench).

Identified waste disposal units contain both RFP and non-RFP waste, which can be characterized as either TRU waste, LLW, or MLLW. Volumes in each of the units were estimated based on available inventory data. For the RFP waste, the percentage of TRU versus non-TRU waste is uncertain. However, for this initial analysis, it is assumed that 50% of the RFP waste could be characterized as TRU waste

with the remainder classified as either LLW or MLLW. The non-RFP waste within disposal sites would be considered as either LLW or MMLW. It also is assumed for this analysis that the interstitial soil, (i.e., 30 cm [1 ft] of the overburden and 30 cm [1 ft] of underburden soil) are contaminated. Figure 3-3 illustrates the surface area and capacity for each of the RFP waste units along with estimated volumes of TRU and non-TRU waste.

Pit/Trench Number	(1) Total Volume of Pit/Trench[a] (m³)	(2) Surface Area of Pit/Trench (m²)	(3) Volume of Non-RFP Waste (m³)	(4) Volume of RFP Waste (m³)	(5) Total Waste Volume[b] (m³)	(5) Total TRU Waste Volume[c] (m³)	(6) Total NonTRU Waste Volume (m³)
1	5,850	2,310	1,460	4,380	5,840	2,190	3,650
2	18,430	7,290	2,820	6,500	9,320	3,250	6,070
3	9,830	3,890	620	1,370	2,000	685	1,305
4	26,250	10,380	1,580	9,320	10,900	4,660	6,240
5	25,550	10,100	780	7,000	7,780	3,500	4,280
6	12,920	5,110	650	6,210	6,860	3,105	3,755
9	10,700	4,230	620	3,400	4,020	1,700	2,320
10	26,250	10,380	2,610	13,300	15,910	6,650	9,260
11	5,840	2,310	3	420	420	210	213
12	7,030	2,780	120	1,770	1,890	885	1,005
Pits Total	148,650	58,780	11,260	53,670	64,940	26,835	38,098
PAD A	16,990	NA	0	10,200	10,200	6	10,200
Pad A Total	16,990	NA	0	10,200	10,200	6	10,200
T1	1,890	750	130	390	520	195	325
T2	1,860	750	70	200	270	100	170
T3	1,830	720	150	440	590	220	370
T4	1,840	730	160	480	640	240	400
T5	1,920	760	170	510	680	255	425
T6	1,840	730	160	480	640	240	400
T7	1,910	750	110	320	430	160	270
T8	1,840	730	160	490	650	245	405
T9	2,020	800	10	30	40	15	25
T10	1,900	750	80	250	330	125	205
Trenches Total	18,850	7,470	1,200	3,590	4,790	1,800	2,990
Volumes Total	184,000	66,000	12,460	67,460	79,930	28,640	51,290

a. Total Volume of Pit/Trench (from Interim Baseline Risk Assessment); for Pad A the total volume was assumed based upon storage configuration
b. Total Waste Volume equals the sum of Volume of Non-RFP Waste (3) and Volume of RFP Waste (4)
c. Total TRU waste volume assumes 50% of RFP Waste (4) except for Pad A where only limited shipments were noted.

Figure 3-3. Disposal unit waste volume estimates.

As shown in Figure 3-3, based upon available inventory data, the disposal units contain approximately 67,460 m³ (88,230 yd³) of RFP waste and approximately 12,460 m³ (16,300 yd³) of nonRFP waste. With the assumption that 50% of the RFP waste in the pits and trenches and approximately 6 m³ (8 yd³) of the waste on Pad A will be classified as TRU waste, the total volume of TRU waste is projected at 28,640 m³ (37,460 yd³). The total volume of non-TRU waste, which will be classified as either MLLW or LLW, is estimated at 51,290 m³ (67,080 yd³).

An estimate of potentially contaminated soil and total TRU and non-TRU waste streams within the disposal units is provided in Figure 3-4.

Pit/Trench Number	(1) Volume of Non-TRU Waste (m³)	(2) Volume of TRU Waste (m³)	(3) Total Waste Volume[a] (m³)	(4) Volume Contaminated Soil[b] (m³)	(5) Volume of TRU-Contaminated Soil[c] (m³)	(6) Volume of NonTRU-Contaminated Soil[d] (m³)	(7) Volume TRU Waste and Soil[e] (m³)	(8) Volume Non-TRU Waste and Soil[f] (m³)	(9) Volume Clean Overburden (m³)
1	3,650	2,190	5,840	1,410	705	705	2,895	4,355	3,520
2	6,070	3,250	9,320	13,550	3,250	10,300	6,500	16,370	11,110
3	1,305	685	2,000	10,200	685	9,515	1,370	10,820	5,930
4	6,240	4,660	10,900	21,670	4,660	17,010	9,320	23,250	15,820
5	4,280	3,500	7,780	23,930	3,500	20,430	7,000	24,710	15,390
6	3,755	3,105	6,860	9,180	3,105	6,075	6,210	9,830	7,790
9	2,320	1,700	4,020	9,260	1,700	7,560	3,400	9,880	6,450
10	9,260	6,650	15,910	16,660	6,650	10,010	13,300	19,270	15,820
11	213	210	420	6,820	210	6,610	420	6,823	3,520
12	1,005	885	1,890	6,830	885	5,945	1,770	6,950	4,240
Pits Total	38,100	26,835	64,940	119,510	25,350	94,160	52,200	132,300	89,590
PAD A	10,200	6	10,210	11,740	6	11,734	12	21,930	12,120
Pad A Total	10,200	6	10,210	11,740	6	11,734	12	21,930	12,120
T1	325	195	520	1,830	195	1,635	390	1,960	1,140
T2	170	100	270	2,050	100	1,950	200	2,120	1,140
T3	370	220	590	1,680	220	1,460	440	1,830	1,100
T4	400	240	640	1,650	240	1,410	480	1,810	1,110
T5	425	255	680	1,700	255	1,445	510	1,870	1,160
T6	400	240	640	1,650	240	1,410	480	1,810	1,110
T7	270	160	430	1,940	160	1,780	320	2,050	1,140
T8	405	245	650	1,640	245	1,395	490	1,800	1,110
T9	25	15	40	2,460	15	2,445	30	2,470	1,220
T10	205	125	330	2,030	125	1,905	250	2,110	1,140
Trenches Total	3,000	1,795	4,790	18,630	1,800	16,840	3,590	19,830	11,370
Volumes Total	51,300	28,600	79,900	149,900	27,200	122,700	55,800	174,100	113,000

a. Total Waste Volume equals the sum of Volume of Non-TRU Waste (1) and Volume of TRU Waste (2)
b. Total Volume Contaminated Soil equals insterstitial soil plus 1 ft contaminated underburden plus 1 ft contaminated overburden
c. Volume TRU Contaminated Soil equals the volume of contaminated TRU Waste
d. Volume Non-TRU contaminated Soil equals the total Volume of contaminated soil (column 4) minus the volume of TRU contaminated soil (column 5)
e. Total Volume of TRU Waste and Soil equals sum of columns 2 and 5
f. Total Volume of Non-TRU Waste and Soil equals sum of columns 1 and 6

Figure 3-4. Disposal unit waste and soil volume estimates.

As shown in Figure 3-4, it is estimated that the designated pits, trenches, and Pad A contain approximately 149,900 m³ (196,060 yd³) of potentially contaminated soil, which includes interstitial soil and 1 ft of overburden and underburden soil. The amount of TRU-contaminated soil was considered to be equivalent to the TRU waste volume in each of the disposal units, which results in a combined total of 55,800 m³ (73,000 yd³) of TRU waste and soil. The remaining 174,000 m³ (227,600 yd³) of waste and soil was considered to consist of both MLLW and LLW. It is also estimated that a retrieval action would require removing approximately 113,000 m³ (147,800 yd³) of clean overburden soil.

3.1.2   Soil Vault Rows and Remaining Trenches

As discussed in the previous section, identified RFP waste disposal sites primarily contain the actinide, nitrate, and VOC COCs. However, certain COCs (e.g., C-14, I-129, Nb-94, and Tc-99) were disposed of primarily as remote-handled waste in the SVRs and within the remaining trenches (Trenches 11 through 58) and pits. Some quantity of waste containing fission and activation products also was disposed of in Pits 8, 9, and 10. The general distribution of COC-bearing waste is shown on Figure 3-5, which is based on partial mapping data that were available at the time this report was being prepared. Because work is still ongoing to map the SDA, all locations and quantities of waste containing fission and activation products in the SDA have not been identified.
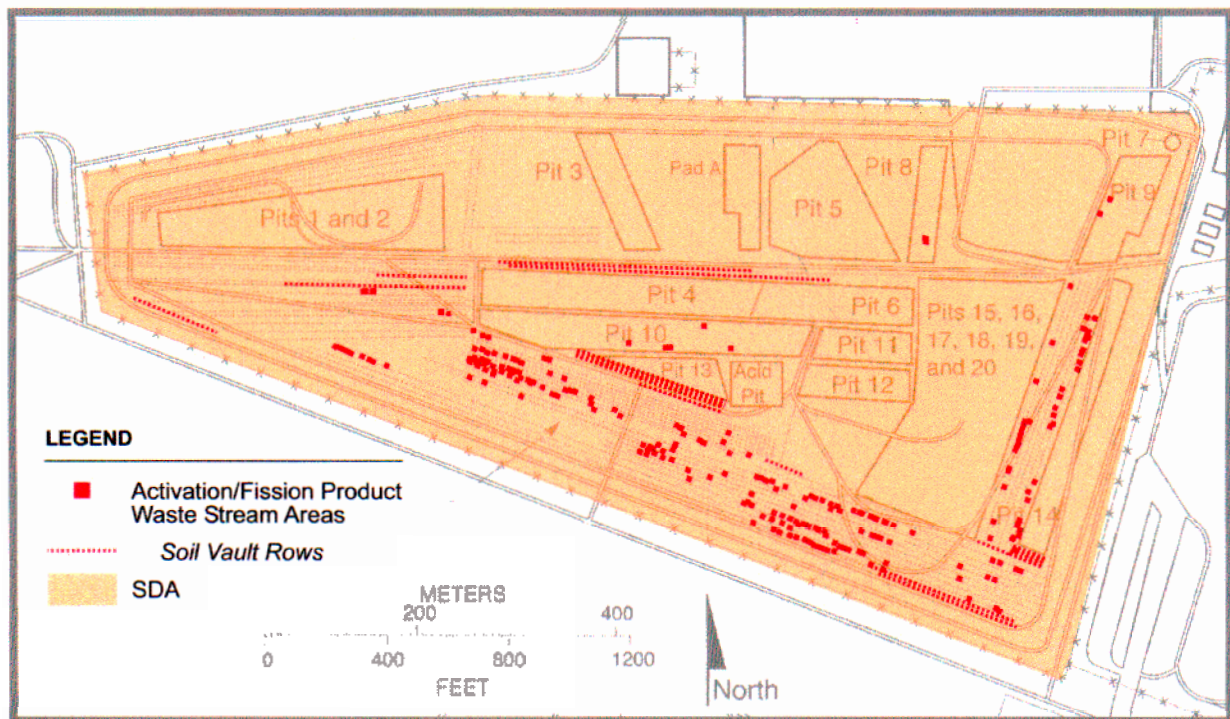
Figure 3-5. Distribution of activation and fission products based on a partial mapping data set.

For each alternative, specific remedial actions also would be directed at these areas. For this analysis, it is assumed that additional remedial measures would encompass all of the SVRs (approximately 550 individual vaults) and selected areas within the trenches, amounting to approximately 1,500 m^2 (15,900 ft^2) of trench.

3.1.3 Special Waste Forms

Research is currently being conducted to verify and quantify special waste forms in the SDA (e.g., irradiated fuel materials and beryllium blocks), which could require specific remediation. Presently, the nature and extent of special waste forms within the SDA are uncertain and therefore will not be directly addressed in this PERA. Remediation requirements for special waste forms will be evaluated during preparation of the WAG 7 feasibility study.

3.2 Assembly of Alternatives

Alternatives presented in this section are developed around specific technology applications, including containment, ISG, ISV, and RTD. These alternatives provide a comparative perspective regarding potential implementation of these technological approaches and their ability to address risks associated with buried waste within the SDA. Therefore, each of the technologies is principally featured in its respective alternative and is primarily focused on remediating RFP waste, as described in the previous section. However, because of variability of waste in the SDA and unique capabilities of featured technologies, using supplemental technologies was required to assemble alternatives to adequately address site risks and achieve the RAOs defined in Section 1. Supplemental technologies have been evaluated for the following:

- Trench and SVR areas containing the activation and fission products

3-6

- Disposal sites containing high concentrations of VOCs

- Pad A waste.

The application of these supplemental technologies for each of the alternatives is summarized in Figure 3-6.

As shown in Figure 3-6, the No Action and the Limited Action alternatives do not include supplemental technologies that specifically address activation products, fission products, high VOC areas, and Pad A. Summary discussions of the application of the supplemental technologies for each of the remaining alternatives are presented in the following subsections.

3.2.1 Containment Alternatives

Containment alternatives, which include both Surface Barrier and Full Containment alternatives, are primarily developed to address buried waste within the SDA as a whole, and therefore are not waste-site-specific technology applications. However, fate and transport modeling indicates that containment alone will not adequately address long-term groundwater risks. For this reason, containment alternatives as presented in this analysis, also include applying ISG in the SVRs and selected trench areas to augment containment technologies and minimize future activation and fission product COC releases from the source term. Containment alternatives also include applying ISTD to address high VOC areas within the source term by extracting and treating organic contamination in these areas.

	Monitoring	Access Controls	Surface Barrier	Subsurface Barrier	In Situ Treatment	Retrieval	Ex Situ Treatment	On-Site Disposal	Off-Site Disposal	Representative Process Options
No Action	✓									
Limited Action	✓	✓	✓*							*Biotic Barrier
Surface Barrier	✓	✓	✓*							*Engineered Multi-Layer Cap
Activation/Fission Waste					✓*					*ISG
VOC Waste					✓*					*ISTD
Pad A Waste						✓		✓*		*Placed Beneath Cap
Full Containment	✓	✓	✓*	✓	✓*					*Engineered Multi-Layer Cap
Activation/Fission Waste					✓*					*ISG
VOC Waste					✓*					*ISTD
Pad A Waste						✓		✓*		*Placed Beneath Cap
In Situ Grouting	✓	✓	✓*							*Engineered Multi-Layer Cap
RFP Waste					✓*					*ISG
Activation/Fission Waste					✓*					*ISG
VOC Waste					✓*					*ISTD
Pad A Waste						✓	✓*	✓		*Ex Situ Stabilization
In Situ Vitrification	✓	✓	✓*							*Engineered Multi-Layer Cap
RFP Waste					✓*					*ISV
Activation/Fission Waste					✓*					*ISG
VOC Waste					✓*					*ISTD/ISV
Pad A Waste					✓*	✓				*ISV
Retrieval	✓	✓	✓*							*Engineered Multi-Layer Cap
RFP Waste						✓	✓	✓*	✓**	*On-Site Landfill - Non TRU Waste **WIPP Disposal - TRU Waste
Activation/Fission Waste					✓*					*ISG
VOC Waste					✓*					*ISTD
Pad A Waste						✓	✓	✓*		*On-Site Landfill

Figure 3-6. Alternative components.

For both containment alternatives, it is assumed that ISG would be used to stabilize any untreated waste units within the SDA, as required to minimize any future subsidence-related damages to the cover system. Further, Pad A waste, as currently configured, is potentially unstable and its ability to support the proposed cover system is questionable. For this reason, containment alternatives assume that the Pad A

waste will be retrieved and placed in a compact and more stable configuration within the SDA before constructing the cover system.

3.2.2 In Situ Grouting Alternative

The ISG alternative is focused on remediating groundwater COCs within the SDA. In general, ISG has been shown to be highly effective in immobilizing a wide range of contaminants and will adequately address the majority of waste streams identified in the SDA. However, high concentrations of salt compounds have been found to interfere with curing cementitious grouts. Past work has demonstrated that, with certain grout formations, competent waste forms could be achieved with waste loading approaching 50 wt% nitrate salt (Loomis et al. 1997a, Spence et al. 1999). For this analysis, it is assumed that nitrate salt waste buried within pits would be effectively stabilized in place using ISG. However, for the Pad A area where a high concentration of stacked drums contains the 745 waste, the effectiveness of ISG is questionable. It is therefore assumed for this alternative that the Pad A waste would be retrieved, processed as required, and stabilized ex situ. Stabilized waste would then be placed back onsite before constructing the final cover system over the entire SDA.

High organic content waste also has been shown to interfere with curing the grout matrix (Armstrong, Arrenholz, and Weidner 2002). A predominant waste type within the SDA consists of contaminated oil and other hazardous chemicals that were stabilized in an absorbent and packaged in drums. It is assumed for this alternative that the areas of high organic concentrations will require pretreatment using ISTD.

3.2.3 In Situ Vitrification Alternative

The ISV alternative is focused on the TRU pits and trenches and Pad A. ISV would remove and destroy organic constituents and encapsulate most of the inorganic constituents within a durable glass-like monolith. This technology will address all of the COCs identified in the ABRA, with the exception of C-14. Potentially this contaminant would not be incorporated into a melt, but instead would remain associated with the metal and pool at the base of the melt. Metal in this pool would be expected to leach at a higher rate, with potentially adverse future effects on groundwater. For this reason, it is assumed for this alternative that waste streams containing C-14 will be treated in place using ISG.

Pad A waste consists largely of closely stacked drums with minimal interstitial soil. This configuration, especially in considering the high-alkali nature of some of the waste, makes successfully applying ISV questionable. It was therefore assumed that the Pad A waste would be retrieved and reconfigured in a subsurface pit within the SDA as required for safe and effective treatment.

It is also assumed that, before implementing ISV at any of the disposal sites, waste would be pretreated to remove most of the water and VOCs using ISTD. This pretreatment is necessary to preclude the potential for a steam or gas explosion when using ISV.

At the completion of in situ treatment operations, this alternative includes constructing an engineered surface barrier over the entire SDA. Before constructing this surface barrier, any untreated waste units would be stabilized using ISG to minimize any future subsidence-related damage.

3.2.4 Retrieval, Treatment, and Disposal Alternative

The RTD alternative is directed at the RFP waste streams located in the TRU pits and trenches and Pad A. However, for this alternative to address RAOs, it must also mitigate activation and fission products located in the SVRs and the remaining trenches. Waste in these areas is primarily

remote-handled waste, for which no disposal sites are presently available. Thus, the assumption is that this waste would not be retrieved, but would be encapsulated or stabilized in place using ISG.

An additional assumption for this alternative is that the high organics areas within the SDA would require ISTD before initiating retrieval activities to minimize VOC management and contaminant control requirements during retrieval.

For this alternative, the retrieved waste will include both TRU and collocated non-TRU (LLW and MLLW) waste. The TRU waste will be packaged for off-Site disposal at WIPP. The non-TRU waste will be treated and placed in an onsite landfill constructed within the limits of the SDA. At completion of retrieval activities, the entire SDA will be covered with an engineered surface barrier to provide long-term stability of the site. Before constructing this surface barrier, any untreated waste units would be stabilized using ISG to minimize any future subsidence-related damage.

3.3 Common Remediation Elements

Alternatives described in the preceding section have a number of common elements, which are required to address waste stream-specific issues and achieve compliance with the RAOs. All alternatives involve implementing a long-term monitoring program to evaluate effectiveness of remedial measures. All alternatives (with the exception of the No Action alternative) also involve implementing institutional controls in perpetuity and placement of a surface barrier to protect any remaining buried waste at the site. In addition, a number of other elements or considerations are common to two or more of the alternatives, including:

- In situ grouting of the SVRs and trench areas containing activation and fission product COC waste.

- Handling and treating Pad A waste.

- Treating high organic waste areas using ISTD

- Controlling emissions from thermal treatment units

- Continuing operation of existing the OCVZ system

- Continuing operation of active disposal cells

- Maintaining and constructing haul roads.

A discussion of common elements associated with each alternative is presented in following subsections.

3.3.1 Long-Term Monitoring

Each alternative would include implementing a long-term monitoring program, which would involve groundwater, vadose zone moisture, surface soil, surface water, and air. It is assumed that monitoring would be performed under INEEL ongoing Site-wide programs. It is also assumed that any future monitoring program would involve existing monitoring locations and new installations would not be necessary. For costing purposes, it was assumed that a monitoring program would extend for a period of 100 years following completion of the ROD. Every 5 years, site reviews would be conducted to evaluate effectiveness of alternatives and the need for any additional monitoring.

3.3.2   Institutional Controls

Institutional controls (e.g., future land-use and site access restrictions) are key components of each of the action-related remedial alternatives. For each alternative, evaluations assume that a perimeter fence system, with appropriate warning signs, would be established and maintained. For evaluation purposes, the system would presumably consist of an 8-ft chain-link fence, with security gates, extending around the entire perimeter of the SDA and completely encompassing any remaining buried waste and constructed surface barriers.

Evaluations also assume that the SDA would be maintained in perpetuity by DOE or other federal agencies. Institutional control measures would be enforced to prevent inappropriate future use of the site and direct contact with remaining contaminants.

The extent of these controls would depend on the aggressiveness of the remedial action. Controls could include specific restrictions on future development of the waste area and designated buffer areas in response to the nature and extent of remaining waste materials. Controls also could include restrictions on groundwater use.

3.3.3   Surface Barriers and Foundation Stabilization

All the alternatives (with the exception of the No Action alternative) include constructing a surface barrier to control future exposure to waste and identified COCs. Cover designs vary, as summarized in Figure 3-7, based on alternative-specific features and nature of waste remaining within the SDA following remediation. An assumption of the evaluations is that design requirements for the surface barrier would be consistent with criteria recently established for the ICDF design, which considered a 500-year flood event, a probable maximum precipitation (PMP) event for surface scour, and a seismic event corresponding to a return period of 10,000 years.

As shown in Figure 3-7, the No Action alternative does not include constructing a surface barrier. For the Limited Action alternative, a biotic barrier is proposed to deter future biotic intrusions into waste. The SL-1 design was identified as the proposed barrier for this alternative, which consists of approximately 6 ft of gravel and cobbles and requires approximately 1.1 million m^3 (1.5 million yd^3) of material.

Alternative	Surface Barrier
No Action	None
Limited Action	Biotic Barrier
Surface Barrier	ICDF Cover
Full Containment	ICDF Cover
In Situ Grouting	RCRA Modified C
In Situ Vitrification	RCRA Modified C
Retrieval	RCRA Modified C

Figure 3-7. Surface barriers.

For both containment alternatives, the ICDF cover was identified as the proposed surface barrier. This INEEL-specific design is intended to provide containment and hydraulic protection for buried TRU waste for a performance period of 1,000 years. The proposed design includes a vegetative erosion control layer, a biointrusion layer, drainage and filtration layers, and a low-permeability membrane resulting in an overall thickness of approximately 5.5 m (18 ft). Approximately 4.1 million m^3 (5.3 million yd^3) of material would be required to construct the barrier.

In situ treatment alternatives (ISV and ISG) and the RTD alternative also include constructing a low-permeability, multilayered cap over the SDA to protect any remaining waste and residual soil contamination by deterring biotic intrusion, facilitating runoff of precipitation, and further reducing infiltration of moisture into the waste zone. As noted in Section 2, the RCRA (42 USC § 6901 et seq.) Modified Subtitle C cap system was identified as the representative cover for these alternatives where

TRU waste would either be treated in place or retrieved. This cover design consists of layers of earth fill, top soil, sand, gravel, and asphalt, with a combined thickness of approximately 1.7 m (5.5 ft). An estimated 2.4 million m^3 (3.2 million yd^3) of material would be required to construct this cover over the entire SDA.

3.3.3.1   Construction Requirements. Surface barriers primarily consist of interlayered sequences of soil and rock materials. For evaluation purposes, cover systems for each alternative are assumed to encompass approximately 110 acres of surface area, comprising the 97-acre SDA with a 13-acre toe. Evaluations assume that the cap would be initially sloped with placing a site-grading fill to facilitate positive perimeter drainage. This fill would crown the 97-area and create a sloping foundation with a minimum surface gradient of 2%. In addition, a perimeter berm would be installed to minimize inundation or damage during possible flooding events. The perimeter berm would be constructed with silt loam obtained from adjacent areas. The berm would extend approximately 30 m (100 ft) from the toe of the cap and would be 2 m (6.5 ft) high, with side slopes of 2 horizontal to 1 vertical (2H:1V). The total length of the berm around the perimeter of the SDA is estimated to be approximately 3,048 m (10,000 ft). Details regarding design elements for the surface barriers, including layer thicknesses and approximate volumes, is presented on Table 3-1.

Table 3-1. Cover design requirements.

Design Element	Material Description	Thickness (in.)	Volume (yd^3)
Modified RCRA Subtitle C Cap			
Cover Layer 1	Topsoil with gravel	20	296,000
Cover Layer 2	Compacted topsoil	20	296,000
Cover Layer 3	Sand filter	6	89,000
Cover Layer 4	Gravel filter	6	89,000
Cover Layer 5	Gravel drainage	6	89,000
Cover Layer 6	Low-permeability asphalt	6	89,000
Cover Layer 7	Asphalt base course	4	59,000
Cover Layer 8	Gravel gas collection	6	89,000
Cover Layer 9	Grading fill—silt loam	120	1,775,000
Slope armor	Fine filter—sand	12	6,000
Slope armor	Coarse filter—gravel	12	6,000
Slope armor	Coarse-fractured basalt	12	6,000
Slope armor	Riprap	36	18,000
Perimeter berm	Unprocessed silt loam	NA	244,200
Berm armor	Riprap	36	15,600
INEEL Site Composite Cover			
Cover Layer 1	Topsoil	12	177,000
Cover Layer 2	Engineered fill—silt loam	96	1,420,000
Cover Layer 3	Fine filter—sand	12	177,000
Cover Layer 4	Coarse filter—gravel	12	177,000
Cover Layer 5	Bio-intrusion barrier—coarse basalt	30	444,000
Cover Layer 6	Coarse filter—gravel	12	177,000
Cover Layer 7	Fine filter—sand	12	177,000
Cover Layer 8	Geomembrane	60 mil	532,000 yd^2

Table 3-1. (continued).

Design Element	Material Description	Thickness (in.)	Volume (yd³)
Cover Layer 9	Compacted clay	24	355,000
Cover Layer 10	Gas collection—gravel	6	89,000
Cover Layer 11	Grading fill—silt loam	120	1,775,000
Slope armor	Fine filter	12	15,200
Slope armor	Coarse filter	12	15,200
Slope armor	Coarse basalt	12	15,200
Slope armor	Riprap	36	45,600
Perimeter berm	Perimeter berm	NA	244,200
Berm armor	Riprap	36	15,600

INEEL = Idaho National Engineering and Environmental Laboratory
NA = not applicable
RCRA – Resource Conservation and Recovery Act

3.3.3.2   Borrow Source Evaluation. Material required to construct the surface barriers includes fine-grained, low-permeability soil, sand, gravel, coarse-fractured basalt, and riprap, in the estimated volumes listed in Table 3-1. A preliminary borrow search was conducted to evaluate availability of onsite or off-Site sources and identify proposed borrow sources for each of the required construction materials. Results of the evaluation are summarized in Table 3-2.

Table 3-2. Required materials for surface barriers.

Material	Function	Haul (mi)	Source
Topsoil	Organic silt loam used to support surficial vegetation.	1.5	This material would be unprocessed organic silt loam obtained from Spreading Area B.
Silt loam (fine grain)	Material used for site grading, berm construction and fine-grained layers within the caps.	1.5	If necessary permits and approvals can be obtained, the majority of material would be unprocessed borrow from Spreading Area B. Suitable material also available from Spreading Area A, Ryegrass Flats, and the Water Reactor Research Test Facility area.
Gravel	Material used for the coarse filter layers within the caps.	2.5	This material would be processed gravel obtained from the Borax Gravel Pit.
Sand	Material used for the fine filter layers within the caps.	2.5	No identified bank run borrow areas are available within the INEEL boundary. This material would be processed sand obtained from the Borax Gravel Pit.
Riprap	Material used for erosion control.	5	The majority of the mined riprap material at the INEEL has been used. This material would be processed material mined from a basalt outcropping 5 mi west of the site
Coarse-fractured basalt	Material used as biobarrier within the caps.	5	This material would be processed material mined from a basalt outcropping identified 5 mi west of the site.
Cobbles	This material would be used as biobarrier material if coarse-fractured basalt is unavailable or is not allowed for such use.	45	The majority of the mined riprap material at the INEEL has been used for other remedial actions at the INEEL. This material would be processed material transported from Idaho Falls.

The primary borrow material required for constructing surface barriers is silt loam. Figure 3-8 shows locations of three potentially available silt-loam borrow sites on the INEEL. These areas are estimated to have available soil volume in excess of 3.5 million m^3 (4.6 million yd^3). The closest borrow areas to the SDA are Spreading Areas A and B (1.5 mi southwest), Ryegrass Flats (15 mi northeast), and the Water Reactor Research Test Facility (40 mi north). The PERA evaluations assume that the majority of silt loam for barrier layers will be obtained from Spreading Area B, but additional evaluations must be performed to validate this assumption. Additional information about borrow sources can be found in the *Environmental Assessment and Plan for New Silt/Clay Source Development and Use at the Idaho National Engineering and Environmental Laboratory* (DOE 1997).

Spreading Area B, which is currently not used as a borrow source, contains deposits of the silt loam material considered most suitable for constructing the compacted clay layer. Over 765,000 m^3 (1 million yd^3) of material are estimated to be available at this location. An assumption for the evaluations is that the regulatory process for allowing borrow activities at Spreading Area B would be successful and the area would be available for WAG 7. Because borrow activities are not currently allowed at Spreading Area B, using this area as a borrow source may entail the following requirements:

- The area must be test drilled to estimate volume.

- The Environmental Assessment Plan must be revised.

- Requirements for an Army Corps of Engineer Section 404 Permit must be considered. Section 404 of the Clean Water Act (EPA 1987) regulates the discharge of dredged or filled material into U.S. waters, including wetlands. Substantive and administrative Clean Water Act dredge-and-fill requirements are applicable or relevant and appropriate to many CERCLA actions, including excavation and disposal of contaminated soil or sediments. However, if excavation activities take place offsite of the RWMC, then the Section 404 administrative permit requirements may also apply.

Figure 3-8. Potential borrow sources.

- Proper handling and disposal of any dewatering fluids from excavating borrow material from the Big Lost River Corridor must be demonstrated.

Processed sand and gravel would be needed for constructing the coarse filter, fine filter, and gravel gas collection layers. These materials would be obtainable from the Borax Gravel Pit located about 2.5 mi from the SDA.
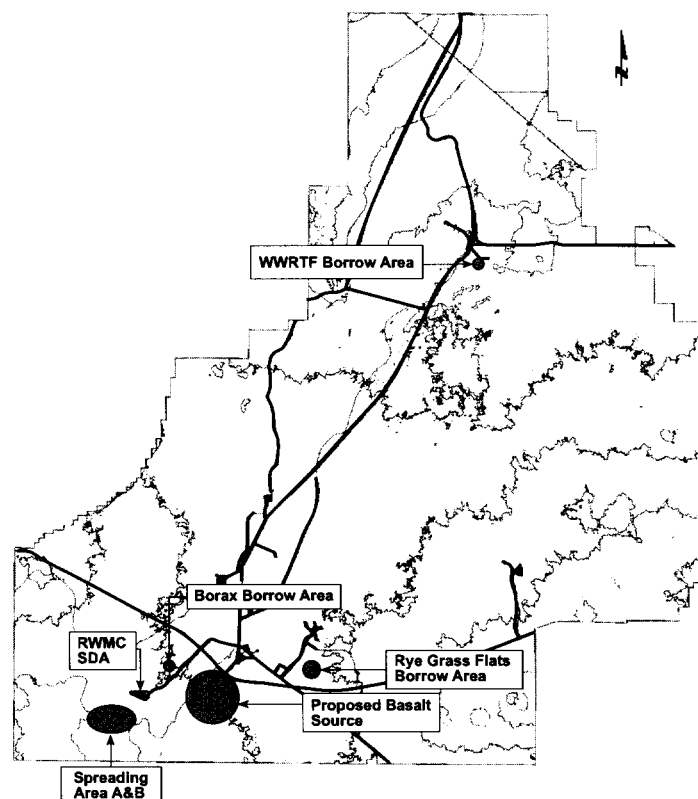
Coarse-fractured basalt will be needed for constructing biotic barriers, and riprap will be needed for erosion control. Because the majority of rock (basalt) once available at the INEEL has been used for other remedial actions at the INEEL, a basalt outcrop about 5 mi from the SDA has been identified for mining to supply these materials. Though cobbles also could be used for the biotic barriers, the nearest apparent source for cobbles is located approximately 45 mi from the SDA in Idaho Falls. The additional cost of this longer haul distance would make cobbles a significantly more expensive construction material than coarse-fractured basalt. Evaluations therefore assume that the basalt outcrop will be mined and the rock will be processed to provide coarse-fractured basalt and rip rap for constructing surface barriers.

3.3.3.3 Foundation Stabilization.
The major implementability issues associated with multilayered, low-permeability capping are the amount of subsidence that can be allowed without damaging the cover, and mitigating measures that must be applied before the cover is constructed. Subsidence is a well-documented, annual occurrence at the SDA. For example, a visual inspection of the SDA performed in April 1999 identified 13 subsidences across a number of pits, trenches, and Pad A. Subsidences ranged from 8 to 300 ft long, 4 to 37 ft wide, and 8 in. to 12 ft deep. Average subsidence length is 60 ft and average subsidence width is 15 ft. The deepest subsidences, however, were approximately 12 ft.

Though modern geosynthetics (e.g., low linear polyethylene) have the high tensile strength and flexibility to accommodate substantial settling, long-lived low-permeability caps generally require a stabilized foundation. Even if subsidences can be bridged by cover materials, sagging and eventual collapse over long time periods should be expected. The low-permeability cap design requires a stable foundation to preserve integrity of infiltration-inhibiting layers. The substantial subsidence currently being experienced could reduce effectiveness of the cap and would be difficult to repair, given the layered nature of the design. Methods to control subsidence will need to be developed and implemented before constructing the cap. Actual foundation requirements will have to be developed as part of remedial design. At this time, grouting is incorporated to stabilize the cap foundation. However, other pretreatments (e.g., dynamic compaction and preloading) could be considered.

Grouting for foundation stabilization would be nonreplacement in situ jet grouting as developed at the INEEL (Armstrong, Arrenholz, and Weidner 2002). This technique, which is described in subsequent sections of this PERA, employs a modified drill rig to inject grout under high pressures into the waste seam. The grout fills all readily accessible void space and cures into a solid monolith. Because the waste and grout monolith is supported on five sides and void space is filled, subsidence is eliminated regardless of the final compressive strength of the grouted media. This principle permits using widely available, inexpensive grouts (e.g., Portland cement) as the solidifying agent.

Unlike grouting for waste treatment, stabilization grouting would not require that grout be intimately mixed with waste or soil, nor would it be required that the grout fill soil pore space or other small void space inside individual waste drums. The assumption for the evaluations is that voids that threaten integrity of the cap are fairly large and would be intersected if grout was injected on an 4-ft center-to-center spacing across the areas requiring stabilization. This spacing does not ensure that every container is intersected, but would be adequate to support the cap. During remedial design, a records review and geophysical program may be performed in an attempt to characterize the size and extent of the large void areas.

During past field trials in simulated buried waste, researchers found that the maximum volume of grout that could be injected using a dense, 0.5 m (20-in.) grid injection spacing was approximately 60% of waste volume. Therefore, it is projected that grouting for foundation stabilization would require approximately 10,300 m^3 (13,500 yd^3) of grout per acre of waste, given the assumption that the volume of the large voids equals 60% of waste volume and that the waste seam is (on average) 4.3 m (14 ft) thick. It

is projected that the production rate for foundation preparation would be substantially greater than that required for waste encapsulation, because of increased spacing and fewer number of required grout holes.

3.3.4 Grouting of Soil Vaults Rows and Trenches Containing Activation and Fission Products

A common element for containment, in situ treatment, and RTD alternatives is in situ grouting of the SVRs and trench areas containing activation and fission product waste. Fate and transport modeling indicates that containment alone (i.e., the construction of engineered low-permeability surface and subsurface barriers) would not sufficiently reduce the release rates of the activation and fission product COCs to protect area groundwater. Furthermore, ISV was not regarded as an effective solution, given the high metal content and concerns that C-14 would not be effectively treated (Thomas and Treat 2002).

Though a detailed analysis of waste streams and engineering design have not been performed, ISG has been identified as the most effective and implementable option. The predominant waste form in these areas is high-activity, remote-handled waste, primarily activated metals. In the SVRs waste was typically dropped into augured holes with heavily shielded or remote discharge equipment. Because of safety concerns when handling high-activity waste and the absence of available disposal options, retrieval was not considered.

Grouted waste forms have been extensively researched for activation and fission products from nuclear reactors, and available data show that COCs (e.g., C-14) have extremely low diffusion coefficients through cementitious grout (Armstrong, Arrenholz, and Weidner 2002). These data suggest that cementitious grout would not only reduce infiltration, slowing corrosion and contaminant release, but would also chemically bind with the COCs. Significantly, past ISG testing has focused on sludge types of waste as found in the TRU pits and trenches. The injection process has not been tested on simulated soil vaults. However, because injection has been used successfully in INEEL soil, the process will be implementable for applying grout in a v-trough pattern around individual vaults.

3.3.5 Handling and Treating Pad A Waste

Pad A waste represents a unique challenge to each remedial alternative. As described in Section 2, the asphalt pad, which is located in the north-central portion of the SDA, was constructed for disposal of packaged, solid, and mixed waste primarily from the RFP. Over 20,000 waste containers, including 55-gal drums and plywood boxes, were placed on the pad. Stacked waste consists primarily of nitrate salt, depleted uranium, and sewage sludge. In 1994, the Pad A cover was reinforced with a 3- to 5-ft-thick vegetated soil layer and a rock armor cover on the south face as a remedial action in accordance with the OU 7-12 ROD (DOE 1994). The covered waste area extends to an average height of 9 m. Since remediation, annual maintenance activities have included repairing subsidence-related damage to the soil cover.

With the exception of the No Action and the Limited Action alternatives, all of the alternatives presented in this analysis are based on the assumption that the Pad A waste would be retrieved, treated, and reconfigured in a compacted layer within the center of the SDA before the placement of the final cover. This action would address the unstable nature of the surface of the Pad A waste pile and potential design issues associated with incorporating the pile into the final cover system. For containment alternatives, preventing future subsidence-related damage to the final surface barrier is critical to ensure its long-term integrity and minimize future maintenance requirements. For the in situ treatment alternatives (ISG and ISV), the assumption was that retrieval of the Pad A waste would facilitate treatment. For the ISG alternative, it was assumed that waste would require specialized grout with an ex situ application to ensure proper treatment, given the high nitrate concentrations in the waste. For the

ISV alternative, the amount of interstitial soil was deemed insufficient to ensure effective vitrification. Therefore, the analysis included the assumption that waste would be retrieved, blended with soil, and restaged in an onsite pit. The restaged waste would then be vitrified in place.

3.3.6   Treating High Volatile Organic Compound Waste

With the exception of the No Action and the Limited Action alternatives, all of the alternatives include the assumption that in situ treatment of the high VOC areas would be required. Such treatment would focus on reducing future operational requirements for the OCVZ system and facilitating the implementation of specific technologies. As discussed in Section 2, though a number of technologies that could provide for in situ treatment of this waste are potentially applicable to the SDA, ISTD by thermal conduction was selected as the representative technology.

The ISTD pretreatment would employ a 2.4 × 2.4-m (8 × 8-ft) array of heated pipes inserted into the ground. Gas extraction pipes inserted next to the heating pipes would be used to collect steam, volatile organic carbon gases, acid gases, and mercury vapors. Each extraction pipe would be equipped with an integral filter to prevent radioactive particles from migrating into the off-gas treatment system. The pressure of the soil overburden and the high temperatures achieved during ISTD would ensure that liquids in sealed containers boil and breach their containers. The maximum temperature that would be reached (800°C) is well below that at which soil and steel melt. The minimum temperature that would be reached (360°C) is that at which metallic mercury boils. Heating would occur over about a 3-month period. Gas cylinders should also be safely breached, because they are constructed with gas vent plugs designed to slowly relieve pressure at approximately 200°C.

From a risk perspective, VOCs of primary concern include CCl_4, PCE, and methylene chloride. Distribution of these compounds is presented in Section 2 (Figure 2-4). As shown, the VOCs are located within portions of the TRU pits and trenches. The highest concentrations of VOCs, including CCl_4, have been noted within the Series 743 organic waste stream from the RFP. Figure 3-9 depicts the general locations of this waste within the SDA. Also indicated on the figure are areas containing stacked Series 743 waste drums where the higher concentrations of VOCs are expected.

The extent of the ISTD application as a pretreatment to address VOCs in the waste is different for each of the alternatives and depends on specific technology requirements and the need to ensure compliance with RAOs. For containment alternatives, it is assumed that ISTD would be implemented to address the full extent of the CCl_4 distribution as depicted on Figure 3-9, which amounts to a total area of approximately 5 acres. Identified in the ABRA as a major contributor to future groundwater risks, CCl_4 is the primary focus of the OCVZ system currently operating at the RWMC to remove VOCs from the underlying vadose zone (see Section 3.3.8). For the ISV alternative, where ISTD is used as a supplemental technology to precondition the waste and minimize the possibility of explosion, the application will be performed over the full extent of the TRU pits and trenches, approximately 17 acres. For ISG, pretreatment is required only in high organic areas to ensure proper implementation of the technology. Pretreatment for the retrieval alternative is required only to minimize material handling requirements. For both of these alternatives, only high organic areas (approximately 1 acre) depicted on Figure 3-9 will be targeted.
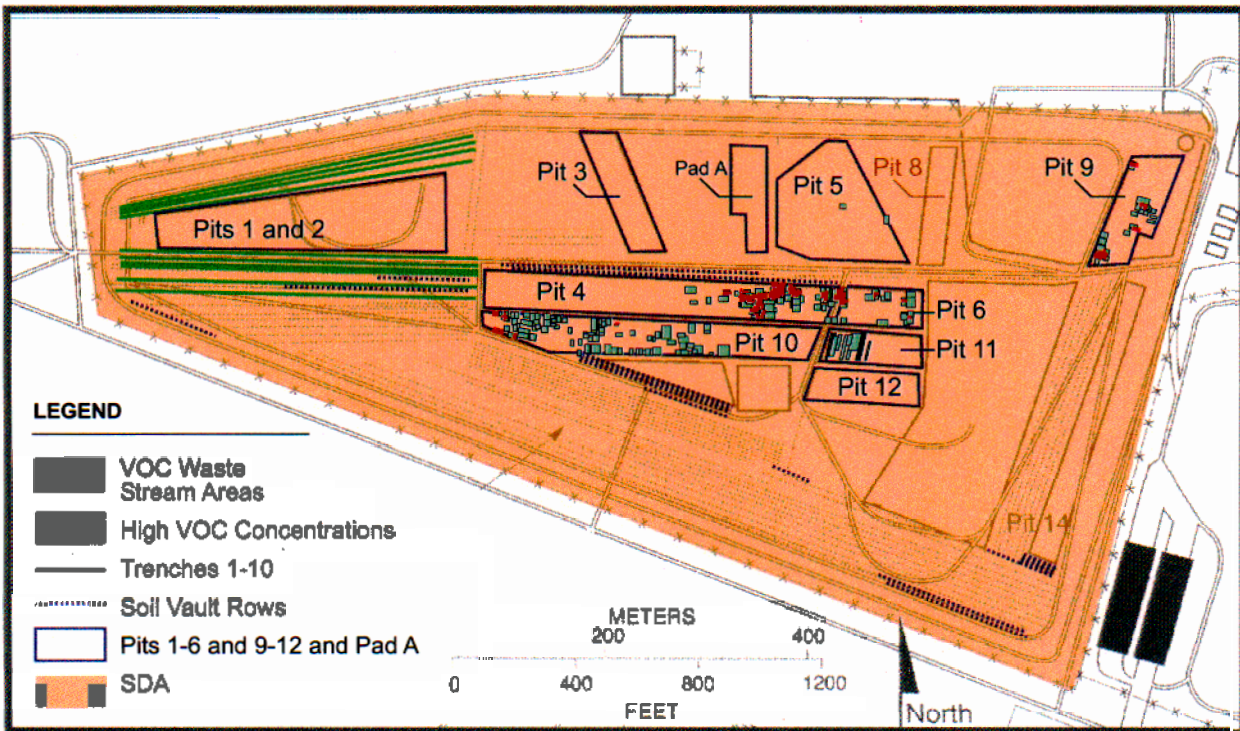
LEGEND

- ■ VOC Waste Stream Areas
- ■ High VOC Concentrations
- — Trenches 1-10
- ·········· Soil Vault Rows
- ☐ Pits 1-6 and 9-12 and Pad A
- ▧ SDA

Figure 3-9. High volatile organic compound waste stream areas.

3.3.7 Air Emissions

Air emissions from the ex situ and in situ treatment systems identified for the alternatives will occur as point and fugitive sources. Systems will be designed to capture air emissions with a negative pressure ventilation system, minimizing the amount of fugitive emissions. Captured pollutants will be directed to an emission control system for treatment. Controlled emission rates of regulated pollutants (nitrogen dioxide, carbon monoxide, sulfur dioxide, particulates, ozone and lead) will be calculated and compared against State of Idaho and federal standards. Emission control systems will be used to control pollutants found to exceed significant levels. It is also assumed that emission controls employed will meet Best Available Control Technology standards for these pollutants. Particulate and nitrogen oxide emissions are anticipated to be primary pollutants of concern.

For the alternatives, air dispersion modeling will be performed on all criteria pollutant emissions to determine potential ambient impact of ISTD and ISV operations on local and regional air quality. Refined modeling using the dispersion model will yield short-range (approximately 50 km) air quality impacts. Compliance with the National Ambient Air Quality Standards (NAAQS) (EPA 1990) will be demonstrated through the modeling. The regional air quality impacts can be determined using the CALPUFF model (Earth Tech 2002), which could also be used to evaluate the potential impacts of system operations on visibility in the regional Class I air quality areas (e.g., Yellowstone National Park, Grand Teton National Park, and Craters of the Moon). In addition, modeling will be used to demonstrate compliance with the Prevention of Significant Deterioration increments on the regional Class I areas. Proposed system designs described in these alternatives are expected to enable the facility to meet the standards. However, if modeling later shows a potential significant impact or violation of the NAAQS, the air pollution control system design will be modified.

Toxic air pollutant standards are given in the Idaho Department of Environmental Quality regulations (IDAPA 58.01.01). The standards consist of emission limits and acceptable ambient air concentrations. Compliance with these standards will be demonstrated to ensure the emissions will not injure or unreasonably affect human or animal life or vegetation. In addition, the IDEQ references EPA regulations and emission standards for radionuclides, including 40 CFR 61, Subpart H, "National Emission Standards for Emissions of Radionuclides" under the National Emission Standards for Hazardous Air Pollutants." Compliance with these standards will also be demonstrated through using emission controls and exposure assessment modeling.

3.3.8   Organic Contamination in the Vadose Zone System

The vadose zone beneath the SDA contains VOCs, primarily in the form of vapors, which have migrated from waste buried in the SDA. In accordance with the FFA/CO (DOE-ID 1991), the OCVZ was identified as OU 7-08. Operable Unit 7-08 addresses organic contamination in the vadose zone beneath the SDA, which extends to the top of the Snake River Plain Aquifer approximately 177 m (580 ft) bgs. The primary source of VOC waste within the SDA is associated with containerized Series 743 organic waste from the RFP (EG&G 1993). Initially, estimates for this waste stream were approximately 335,000 L (88,400 gal) of Texaco Regal Oil, CCl_4, and other miscellaneous organics. However, recent analysis of data indicates that a much larger initial source estimate in the volume of CCl_4 (Miller and Varvel 2001). Completion of an RI/FS for OU 7-08 led to a final ROD in 1994, which identified extraction and destruction of the organic vapors as the selected remedy. A series of vapor extraction wells was installed within the SDA with an off-gas treatment system designed to destroy extracted vapors. Since January 1996, when remediation began, approximately 105,000 lb of total VOCs have been removed and treated.

The primary RAO identified in the OU 7-08 ROD is to ensure that risks to future groundwater users are within acceptable guidelines and that future VOC concentrations in the aquifer remain below federal and state drinking water standards. All of the alternatives are designed to accommodate the continued operation of this OCVZ system. Cost estimates for alternatives include capital costs to extend extraction wells, reconstruct header lines, and relocate treatment units as required for the continued operation of the system. No costs, however, were assumed for any future operation and maintenance requirements.

3.3.9   Active Disposal Cells

Current operations within the SDA consist of subsurface disposal of LLW in Pits 17 through 20. Waste materials that meet WAC are currently stacked in the pits to a maximum height of 24 ft with forklifts and cranes. As areas become full, waste is covered with a minimum of 3 ft of soil and the area is seeded. The closure date is uncertain. For this PERA, it is assumed that that the final surface cap systems proposed for individual alternatives would be extended to cover active cells and a staged approach to accommodate continued operation of these active disposal sites would be required. Specifically, installing the final cap identified for each remedial alternative includes a construction phase for these active areas with a start date of 2020.

3.3.10   Haul Roads

Evaluations presented in this PERA assume that the existing road system within the INEEL would be used to transport materials to and from WAG 7, and the cost estimate for each of the alternatives includes the expense for maintaining these roads. A secondary assumption for each of the alternatives is that approximately 2 mi of new gravel haul road would be required to obtain access to additional borrow sites.

3.4 Initial Screening Criteria

The initial screening of alternatives follows CERCLA guidance to identify an appropriate number and range of remedial alternatives to be retained for detailed analysis. As outlined in *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1988), the evaluations assess each alternative's performance according to three general screening criteria, which are detailed in Figure 3-10:

- Effectiveness—These criteria refer to short-term and long-term protection of human health and the environment that an alternative provides. In this application, short-term refers to the implementation period (the duration of the remedial action) and includes potential worker exposure issues and potential uncontrolled releases to the environment. Long-term refers to the period following remediation and includes considerations for permanence and reversibility. Reduction of toxicity, mobility, and volume of contaminated material is also a measure of an alternative's long-term effectiveness.

Screening Criteria Parameters		
Criterion	**Time Interval**	**Parameters**
Effectiveness	Short-Term (Implementation Period)	Protection of: • Human health • Environment
	Long-Term	Reduction of: • Mobility • Toxicity • Volume
Implementability	Short-Term (Implementation Period)	Technical Feasibility • Construction • Operation • Maintenance

	Long-Term	Administrative Feasibility
		 • Availability of:
		   – Services
		   – Equipment
		   – Personnel
		   – Stakeholder acceptance

Cost	100 Years	• Capital costs • Operating costs • Monitoring and maintenance

Figure 3-10. Screening criteria parameters.

- Implementability—These criteria refer to technical and administrative issues pertaining to the feasibility of implementing an alternative. *Technical* feasibility includes construction, operation, and maintenance required for remediation. *Administrative* feasibility includes regulatory and public acceptance, availability of services and specialized equipment, and personnel requirements. Short-term implementability refers specifically to the duration of the implementation period, while long-term implementability refers to the operation, maintenance, and institutional control period thereafter. Uncertainty management concerns and the alternative's flexibility in response to varied and unanticipated future conditions are also elements of the long-term implementability assessments.

- Cost—This criterion refers to the relative magnitude of capital and operating costs for an alternative. For this analysis, operational costs are estimated for a 100-year period following the initiation of the remedial action. Both capital and O&M cost estimates are developed and presented in terms of total dollars and net present value. Costs also include a contingency, which was developed for each alternative based upon complexity and uncertainty associated with implementation. A detailed breakdown of the cost basis for each alternative is presented in Appendix D.

Brief descriptions of the alternatives, along with results of comparative screening analyses, are presented below.

3.5 No Action Alternative

3.5.1 Alternative Description

Formulating a No Action alternative is required by the NCP (40 CFR 300.430[e][6]) and by EPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1988).

The No Action alternative serves as the baseline for comparing remedial action alternatives. For WAG 7, this alternative would include only monitoring and require no direct action to treat, stabilize, or remove contaminants. It is assumed for this alternative that long-term monitoring would be conducted on groundwater, vadose zone moisture, surface soil, surface water, and air for a period of 100 years. Details regarding extent of the assumed program are provided in Section 4 and Appendix D.

3.5.2 Effectiveness, Implementability, and Cost

This comparatively inexpensive alternative would be easily implemented, incurring only costs associated with long-term monitoring. However, the alternative offers no reduction in mobility, toxicity, or volume of contaminants within the SDA. Because the site presents unacceptable risks to human health and the environment, the No Action alternative does not satisfy the RAOs. The estimated total monitoring cost for this alternative is $38.5 million. Net present value cost for the alternative is estimated at $9.6 million.

3.6 Limited Action Alternative

3.6.1 Alternative Description

The Limited Action alternative addresses the RAOs by first establishing administrative policies and restrictions that limit and control access to site contaminants. Various local and state ordinances and statutes, deed notices, and public advisories would be combined to control future site use. For WAG 7, the Limited Action alternative would further establish groundwater use restrictions to prevent future well drilling and prohibit future use of groundwater within the potentially affected area of the Snake River Plain Aquifer.

This alternative entails no treatment or disposal of source materials and would not result in any reduction in mobility of contaminants. However, as indicated in Figure 3-11, other components of this alternative involve placing and maintaining a biotic surface barrier and a perimeter fence to control site access and prevent direct intrusion into waste. As presented in Section 2, the SL-1 design (WAG 5) was identified as the representative biotic barrier for purposes of this analysis. This established cover design, which has been used at other INEEL sites, consists of approximately 6 ft of granular materials, including gravel, and cobble layers with a protective riprap cover. An estimated 1.1 million m^3 (1.5 million yd^3) of granular material would be required to complete constructing a barrier over the entire SDA. During cover placement, surface water controls and diversion systems needed to prevent inundation and damage during projected future flooding events would also be constructed. This cover system is designed to prevent biotic intrusion, but does enhance surface water infiltration.
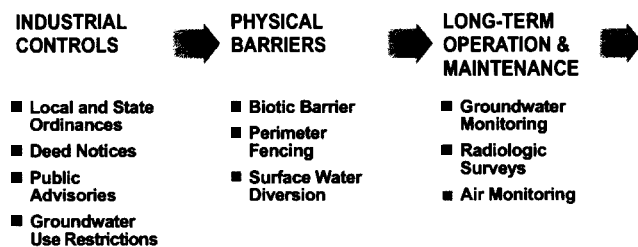

Figure 3-11. Limited Action Alternative schematic.

Long-term monitoring conducted through aquifer well sampling, lysimeter sampling, radiological surveys, and air sampling are long-term protective measures of this alternative. The DOE-ID, IDEQ, and EPA would evaluate effectiveness of the Limited Action alternative components during subsequent 5-year reviews, and would define any additional environmental monitoring necessary. Routine maintenance—a basic assumption of this alternative—would be performed to address potential problems (e.g., burrowing animals and erosion).

3.6.2   Effectiveness, Implementability, and Cost

The Limited Action alternative is potentially effective in protecting human health because institutional controls and biotic barrier operate in conjunction to prevent direct access to site contaminants. However, the alternative does not achieve full compliance with the RAOs. It neither reduces mobility, toxicity, or volume of contamination within the SDA nor directly addresses or inhibits the groundwater migration pathway. Further, placement of the biotic barrier system will result in an increase in infiltration rates. Given this alternative, the site would continue to affect water quality with future contaminant levels exceeding acceptable human health risk levels.

The Limited Action alternative is easily implemented because specified actions would essentially continue existing management practices at the site. Construction of the biotic barrier involves conventional earthwork operations with suitable construction materials readily available from either on-Site or off-Site borrow sources. Worker protection measures currently implemented under DOE orders would remain in effect for the duration of occupational activities. Groundwater and vadose zone monitoring would be performed in accordance with current site practices. Site inspections would be performed twice a year, with cover maintenance, surface water diversion, and fence maintenance performed on an as-needed basis.

The capital cost for this alternative is projected to be relatively low compared to the assembled containment, in situ treatment, and retrieval alternatives. Cost for installing the barrier itself is estimated to be $144 million, including contingency. Because this installation primarily involves a standard earthwork operation requiring no intrusive work, the potential for a significant cost increase resulting from uncertainties in subsurface conditions, technology application, and waste inventory is minor compared to the more extensive in situ treatment or retrieval alternatives. In addition, because this barrier is relatively self-healing, only minor maintenance costs are anticipated. Long-term monitoring and maintenance costs are estimated to total approximately $38 million, including contingency.

3.7   Containment Alternatives

Containment alternatives address WAG 7 RAOs by inhibiting human and environmental exposure pathways to buried waste. Physical barrier(s) and other controls will be designed to deter human and biotic intrusion into waste and control contaminant migration by minimizing surface water infiltration. For the purpose of this initial screening activity, two containment alternatives, structured to provide a range of protectiveness, were developed, as follows:

- Surface Barrier alternative—This alternative requires placement of a long-term, multilayer, low-permeability cap over the SDA. For purposes of this analysis, the cap design for the ICDF landfill was selected. This design includes a low-permeability layer to control surface water infiltration and a biotic barrier to prevent intrusion into waste by burrowing animals and deep-rooted plants. The cap design also includes a gas collection layer to address any future VOC releases from buried waste.

- Full Containment alternative (encapsulation)—This alternative prescribes the multilayer, low-permeability cap, as identified for the Surface Barrier alternative, with adding a perimeter bentonite slurry wall tied to an underlying horizontal grout barrier to attain full containment of the contaminated area.

Institutional controls would be added to these alternatives to restrict site access and future land uses in perpetuity. As part of either alternative, environmental monitoring, cap integrity monitoring, and maintenance (e.g., repair of any observable degradation such as cracks, erosion, and biotic intrusion) would be conducted on an annual basis, and provisions would be established for physical access restrictions (e.g., fencing).

To meet RAOs, a number of other supplemental technology applications are required that are common to both containment alternatives, as discussed in Section 3.3. These technology applications are designed to treat specific COC waste within the SDA that could pose a future threat to human health and the environment and provide a stable foundation area for constructing a surface barrier. Common supplemental technology applications for containment alternatives include:

- Treating activation and fission products—Fate and transport modeling indicates that containment technologies alone will not be sufficient for mitigating future impacts on area groundwater from the more mobile fission and activation products within the SDA. Therefore, waste streams containing these COCs within the SVRs and trenches, as shown in Figure 3-5, would be treated in place with the ISG technology.

- Treating VOCs—The assumption for both of the containment alternatives is that high VOC areas within the SDA, shown on Figure 3-9, would be pretreated by ISTD before the surface barrier construction.

- Foundation stabilization—Site preparation for both containment alternatives includes subsurface stabilization to ensure a solid foundation for the cap and minimize future subsidence-related maintenance requirements. Evaluations include the assumption that a grouting program would be designed and implemented as required to specifically stabilize individual subsurface disposal areas.

- Pad A retrieval and placement—Given the unstable nature of the surface of the Pad A and waste pile and potential design issues associated with incorporating the pile into the final cover system, the assumption for both alternatives is that waste and soil on the pad would be retrieved and reconfigured in a compacted layer within the center of the SDA before the initial cap layers are placed.

Site preparation for both alternatives includes initial site grading to facilitate pretreatment operations, preparation of borrow sites, and abandonment and either relocation or extension of existing well systems (monitoring and vapor extraction wells) within the SDA boundary.

Following subsections provide descriptions of both containment alternatives.

3.7.1 Surface Barrier Alternative Description

This Surface Barrier alternative would include constructing a multilayer, low-permeability cap over the entire SDA. An overview of the construction processes of this cap and other technology applications required for this alternative are shown in Figure 3-12. Design elements of the surface barrier include:

- Control surface water infiltration to minimize future releases from source term to the underlying vadose zone and area groundwater

- Facilitate and control surface water runoff from the SDA

- Incorporate surface water diversion systems to prevent inundation and damage during potential future flooding events

- Employ both a biotic barrier to prevent direct intrusion into waste and a gas extraction and treatment system to control gas emissions from the landfill.

SITE PREPARATION
- Abandon/Extend Existing Wells
- Prepare Borrow Sites
- Initial Site Grading

FOUNDATION TREATMENT
- In Situ Grouting of Activation and Fission Product Wastes
- In Situ Thermal Desorption (ISTD) of High VOC Wastes
- In Situ Grouting for Subsidence Control
- Reconfiguration of Pad A Wastes

CONSTRUCT CAP
- Gas Management
- Cap Section
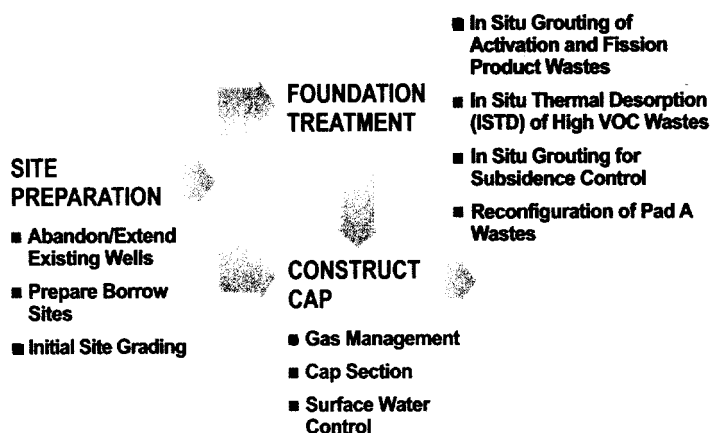- Surface Water Control

Figure 3-12. Surface Barrier alternative schematic.

To provide long-term protection, the cap system must be designed to address potential catastrophic events (e.g., design-life earthquakes, projected maximum flood events, and other natural occurrences). As discussed in Section 2, the proposed long-term cap design for the ICDF landfill (shown in Figure 3-13) was selected as the representative option for this analysis. Designed to address INEEL-specific environmental considerations, this long-term cap provides a degree of protectiveness similar to that of the design for the DOE Hanford CERCLA Disposal Facility. The established Hanford design, having received agency approval, has been successfully installed at waste sites similar to the SDA. The ICDF cap design also was preferable because it uses a geomembrane and clay layer that is more resistant to damage from subsidence than the asphalt layer of the Hanford cap design.

With a projected design life initially estimated at 1,000 years, the cap is structured to minimize surface water infiltration and maximize runoff. The design itself includes a soil cover over a capillary break. The soil serves to store infiltrating water and then release it by evaporation and transpiration via plant roots. This basic design has been shown to be effective in minimizing infiltration into underlying waste in arid and semiarid regions (Khire, Benson, and Boscher 2000). In its simplest form, the design concept relies on fine-grained soil overlying a coarser grained layer. The contrast in unsaturated hydraulic properties between the layers restricts water movement across the interface. In a recent study prepared for the ICDF design (Crouse 2002), the soil cover model was used to evaluate long-term infiltration rates through the proposed ICDF cover. The model was used to simulate average and extreme climactic conditions. Results for extreme climactic conditions show a maximum infiltration rate of 0.49 mm/year (1.5E-09 cm/second).

As shown in Figure 3-13, the proposed design includes a vegetated erosion control layer, a biointrusion barrier, drainage and filtration layers, and a low-permeability geomembrane layer. These layers of fine- and coarse-grained soil and rock over a thick layer of earth fill result in a cap system with a maximum overall thickness of approximately 5.5 m (18 ft). An estimated 2.7 million m³ (3.5 million yd³) of material would be required to construct a barrier over the entire SDA, with an additional 1.4 million m³ (1.8 million yd³) needed for placement of grading fill required to initially crown the site. It is assumed for this analysis that sufficient suitable cap materials are available from either on-Site or nearby off-Site sources. However, a detailed borrow-source evaluation will be required to verify availability of specific materials required for construction.

3.7.2 Full Containment (Encapsulation) Alternative Description

The Full Containment alternative includes complete encapsulation of the SDA waste within low-permeability horizontal and vertical barriers. Figure 3-14 presents an overview of the sequenced construction activities required for Full Containment, and Figure 3-15 provides a conceptual view of the alternative. The surface barrier design would be identical to that of the long-term composite cap design presented for the previously discussed Surface Barrier alternative. However, this alternative would add a vertical, low-permeability barrier to the cap to bound the perimeter of the source term, preventing lateral moisture infiltration. This vertical barrier would be anchored in an underlying horizontal grout barrier, which would extend completely beneath the SDA and fully encapsulate buried waste.
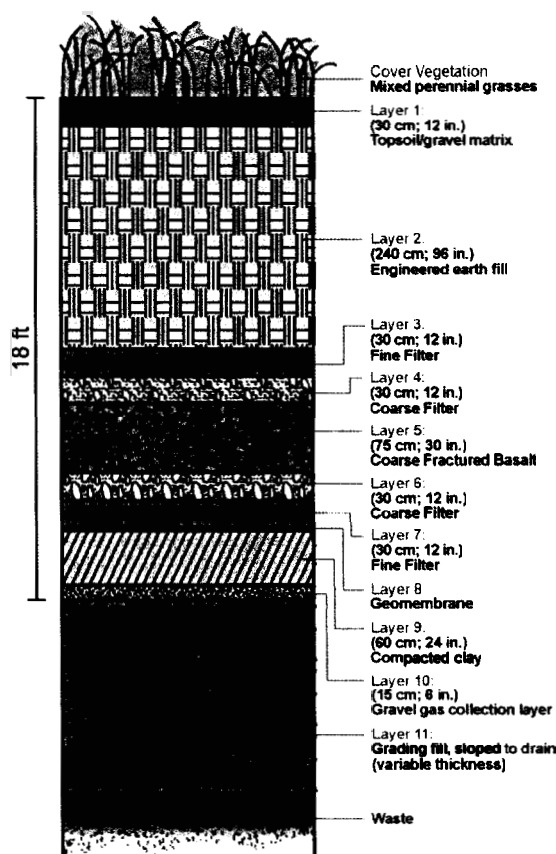
INEEL Site Composite Cover

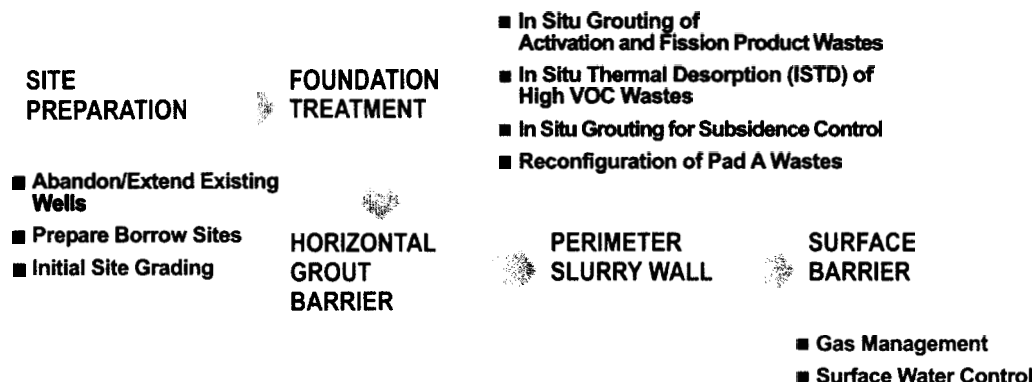Figure 3-13. INEEL CERCLA cover system.

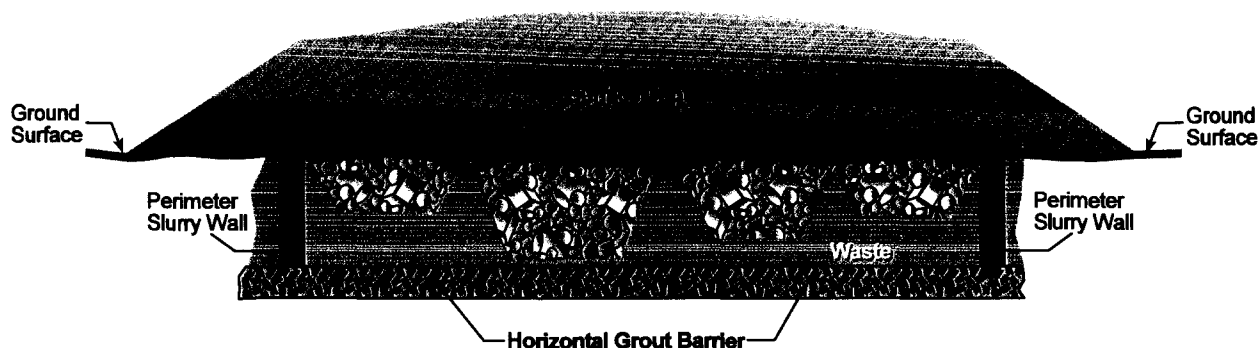Figure 3-14. Full Containment alternative schematic.

Figure 3-15. Full Containment alternative section view.

Following sections describe construction steps needed for this alternative in addition to those described for the Surface Barrier alternative.

3.7.2.1   *Vertical Perimeter Barrier.* The technology screening evaluation conducted in Section 2 identified the bentonite slurry wall as the preferred technology for constructing the subsurface vertical perimeter barrier. Slurry wall construction is a well-established barrier technology commonly used at hazardous waste sites to prevent and control the lateral spread of contaminants. The wall would extend around the entire perimeter of the SDA—a distance of approximately 3,048 m (10,000 ft). The required maximum depth of the wall is 9.1 m (30 ft).

Standard earthwork equipment could be used for wall construction, which involves a 0.9-m (3-ft) minimum-thickness trench being continuously excavated and backfilled with a slurry of bentonite and soil. When properly installed, a slurry wall can achieve permeability values of 1E-07 cm/second or less.

3.7.2.2   *Horizontal Subsurface Barrier.* A number of construction approaches could be considered for encapsulating grout beneath the SDA, but as described in Section 2, a jet grouting vertical technique was identified for this analysis. The technology involves injecting the grout into the underlying formation at high pressures in a grid pattern with overlap to achieve continuity. The horizontal barrier would extend beyond the edge of waste and out to the proposed location of the vertical slurry wall. The slurry wall would be excavated into the grout layer to provide continuous vertical and horizontal barriers.

Vertical drilling and grouting would be used to install a horizontal barrier beneath the SDA. In an effort to minimize the potential for surface contamination spread, grouting could be accomplished using a sonic drilling rig to install 6-in. casing equipped with a manufactured cement plug and drive point. Casing containing the grout plug would be direct-driven through waste to the basalt-alluvium contact without generating drill cuttings or drilling fluids. After the 6-in. casing is secure, a 5-in. rotary drill could be run through the casing. The grout plug would be drilled out of the bottom of the casing, and drilling would be continued up to 1.5 m (5 ft) beyond the basalt-alluvium contact. On reaching desired depth, the drill stem would be removed and grout would be injected into the hole under pressure to construct a continuous horizontal barrier. Grout pressures and uptake into the formation would be monitored during construction to determine borehole spacing needed at various locations in the basalt formation. For this analysis, an average borehole spacing of 3 m (10 ft) was assumed for installing the horizontal barrier.

Several types of grout could be considered, including cement-based and chemical-based grouts. Cement-based grout is commonly used for grouting in highly permeable formations. However, selecting an appropriate grout type may require a substantial amount of testing because the SDA basalts are highly variable in porosity and permeability. Despite the fact that permeabilities ranging from 1E-04 to 1E-12 cm/sec have been achieved in some formation grouting applications, the effectiveness of such grouts beneath the SDA is difficult to predict. Because the soil and basalt subsurface is so variable, complete containment would potentially not be achieved.

3.7.3 Evaluation of Containment Alternatives

A comparison of the containment alternatives based on initial screening criteria of effectiveness, implementability, and cost is presented below.

3.7.3.1 Effectiveness. Both of the containment alternatives, if properly designed and maintained, would be effective, as both address the project RAOs and protect human health and the environment. Placement of the long-term cap would prevent direct access to waste by both human and ecological receptors. The cap would be designed to control migration of contaminants and protect groundwater. In addition, both alternatives include ISG treatment to reduce mobility of activation and fission product COCs within the SDA source term. Alternatives also include application of ISTD within areas containing organic waste to reduce future VOC releases to the vadose zone and minimize future operational requirements for the OCVZ system. Fate and transport modeling shows that the cap, in conjunction with proposed ISG and ISTD treatments, would be protective.

The relative effectiveness of the Surface Barrier alternative compared to the effectiveness of the Full Containment alternative is difficult to quantify. As a stand-alone alternative, the long-term surface barrier can achieve project RAOs and maintain risk levels within acceptable limits. The perimeter slurry wall of the Full Containment alternative would provide an additional degree of protectiveness by preventing lateral moisture migration or groundwater flow from encroaching beneath the cap. However, given subsurface hydrologic conditions within the SDA, little lateral groundwater flow exists in the shallow vadose zone soil. The only documented perched water conditions beneath the SDA are associated with sedimentary interbeds, at depths of 100 to 220 ft below existing grade. Previous infiltration studies conducted in the area indicate that flow in this soil is primarily vertical. Consequently, surface water would have to be ponded in an area immediately adjacent to the cap for infiltrating water to have any potential impact on waste. To account for this potential condition, appropriate surface water control measures will be incorporated into the design of the cover system.

Additional protection afforded by the underlying horizontal grout barrier is also questionable. This barrier would protect against source term inundation by any upwardly moving groundwater—a condition that could be caused in this area by rising perched water conditions resulting from temporary flooding events. However, given that the shallow vadose zone does not support developing perched water conditions near the surface, this situation is unlikely to arise. Furthermore, infiltration rates projected for the proposed surface cap system indicate that any overall decrease in vertical release rates from the source term resulting from the placement of the grout barrier would be minimal. Using cement-based grout, overall permeability of the horizontal subsurface barrier would be unlikely to approach that of the surface barrier; possibly, some zones or fractures would not be fully sealed by grout. Therefore, vertical infiltration in the waste zone would be primarily controlled by the integrity and permeability characteristics of the surface barrier. An additional concern with installing the subsurface barrier is the bath tub effect that could be created in localized areas where moisture would tend to collect, which potentially could result in saturating portions of the source term.

The short-term effectiveness concerns associated with the Full Containment alternative would be significantly greater than for the Surface Barrier alternative. Potential worker exposure during implementation is the primary issue. During constructing the surface barrier for either of the alternatives, workers may be exposed to radiation, VOCs in the breathing zone, and construction hazards. Both of the alternatives also include localized applications of ISTD and ISG, posing short-term risks associated with these intrusive activities. The Full Encapsulation alternative, however, would also require an extensive drilling program throughout the full extent of the SDA for installing a subsurface horizontal barrier. This installation would present workers with a significantly higher potential of direct contact with buried waste.

3.7.3.2 ***Implementability.*** The technical feasibility of implementing the Surface Barrier alternative is high compared to the Full Containment alternative. For the Surface Barrier, implementation would not depend on specific waste stream or inventory information and thus would not require specific source term definition. As a result, implementing the technology would not be subject to delays and additional costs resulting from field modifications caused by unexpected variations in the waste stream or the inability of specific treatment technologies to achieve remedial design requirements. However, for installing the subsurface horizontal barrier required in the Full Containment alternative, construction delays could be experienced if the actual borehole spacing is significantly different from the spacing estimated during design, or if problems are encountered in providing the required spacing because of waste obstructions.

For the Surface Barrier alternative, construction could be executed with standard earthwork equipment, as demonstrated by the successful construction of similar barriers at other DOE facilities. It is assumed for this analysis that material required to construct the barrier for both containment alternatives is available from suitable soil and rock borrow sources located within a 20-mi radius of the SDA. A detailed borrow source evaluation will be necessary to assess suitability of local materials and identify specific borrow sites.

Conversely, installing the subsurface horizontal barrier for the Full Containment alternative would require specialized drilling and grout injection equipment. In addition, ensuring the successful completion of a continuous horizontal barrier beneath the SDA source term would be difficult. Verifying the integrity of the horizontal barrier could require installing and monitoring neutron probes and possibly lysimeters.

3.7.3.3 ***Cost.*** An initial cost estimate was performed for this initial screening to provide a comparative perspective of construction-related costs for each of the two containment alternatives. Estimated total costs for the alternatives, in fiscal year (FY) 2002 dollars, are provided in Table 3-3.

Table 3-3. Total estimated costs for the Surface Barrier and Full Containment alternatives.

Cost Element (FY 2002 dollars)	Surface Barrier ($M)	Full Containment ($M)
Capital costs	796	1,146
Operation and maintenance costs	46	46

Both alternatives would incur costs for constructing the surface barrier—estimated at approximately $796 million. This cost includes the required ISG programs for waste treatment and foundation stabilization, the ISTD pretreatment program, and the processing of the Pad A waste. Additional costs for the Full Containment alternative are projected to be relatively high because of contaminant control and worker protection requirements for constructing the slurry wall and horizontal barrier systems. Capital costs for this alternative are estimated at approximately $1,146 million, which could be subject to increases related to uncertainties in subsurface conditions and requirements to maintain worker safety and contaminant control. Monitoring, access restrictions, and maintenance costs should be similar for each containment alternative.

3.8   In Situ Treatment Alternatives

Two in situ treatment alternatives have been developed for the purpose of this initial screening activity. These involve two specific technologies that have been extensively researched at the INEEL to evaluate site-specific application requirements:

- In Situ Grouting alternative—This involves applying ISG to stabilize buried waste and contaminated soil in place.

- In Situ Vitrification alternative—This involves applying ISV to treat and stabilize buried waste and contaminated soil in place.

As discussed in Section 2.1, these technologies focus primarily on the in situ treatment of the disposal units within the SDA containing the RFP waste, including Pits 1 through 6, Pits 9 through 12, Trenches 1 though 10, and Pad A. Each alternative includes the following components:

- Using ISTD as a preconditioning step

- Placing a protective cover over the entire SDA

- Restricting site access in perpetuity with institutional controls

- Evaluating effectiveness of remedial action with environmental monitoring.

Each of the alternatives additionally provides for in situ grouting of waste deposited in other areas that contain non-TRU groundwater COCs. These areas include the SVRs and specific disposal locations within the remaining trenches. Both in situ treatment technologies would retrieve waste from Pad A for ex situ treatment and subsequent onsite disposal beneath the cap. For the ISG alternative, Pad A waste retrieval is necessary to stabilize the high nitrate salt content. For the ISV alternative, Pad A waste retrieval is necessary to properly configure waste to facilitate a safe and effective treatment using ISV.

3.8.1   In Situ Grouting Alternative Description

This alternative would treat source materials within the SDA with the ISG technology. Individual elements associated with implementing this alternative are presented in Figure 3-16. As shown, the alternative includes a pretreatment stage using thermally enhanced SVE with ISTD to address high organic areas (see Section 3.3.6) and the retrieval and ex situ treatment of the Pad A waste (see Section 3.3.5).

In situ grouting is a technique developed in the construction industry and recently adapted for environmental use. The process entails injecting a slurry-like mixture of cements, chemical polymers, or petroleum-based waxes into contaminated soil or a waste landfill. Grouts are specially formulated to encapsulate the contaminants, isolating them from the surrounding environment. As used in the environmental industry, the process employs nondisplacement jet grouting, whereby soil and waste debris are mixed with grout-forming materials in the subsurface, creating a large grout monolith (DOE-ID 1999; Loomis et al. 1997b). Grouting is accomplished without displacing contaminants or debris or causing the ground to heave. Overall volume of the waste site remains constant, but density of the site is substantially increased as grout fills void spaces between discreet waste components.

In situ grouting has been approved by regulating agencies and implemented on small-scale sites at Oak Ridge National Laboratory, the Savannah River Site, Brookhaven National Laboratory, and the Acid Pit within the SDA (Armstrong, Arrenholz, and Weidner 2002). Though ISG has not been applied to sites as large or with as many radiological and chemical hazards as the SDA, research has been conducted at the INEEL in an effort to evaluate the efficacy of ISG. Results of past applications at other sites and the INEEL research are promising. An evaluation of the technology and application to the SDA conditions, including a summary of ISG case histories, is provided in the supporting report developed for this analysis (Armstrong, Arrenholz, and Weidner 2002).
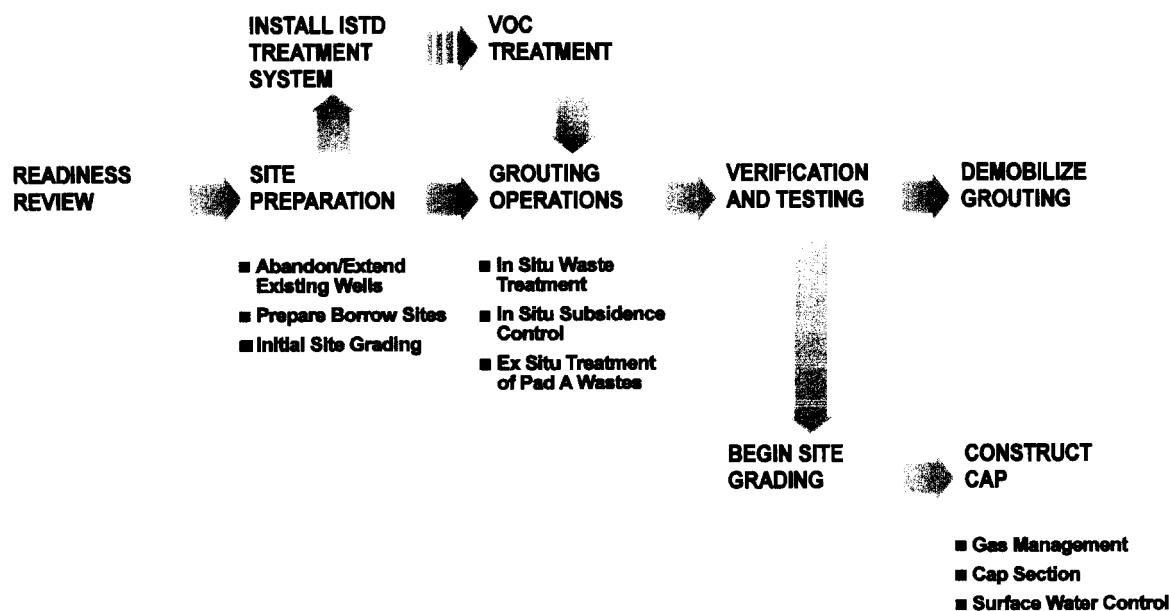
INSTALL ISTD
TREATMENT
SYSTEM
→
VOC
TREATMENT

↑   ↓

READINESS   SITE   GROUTING   VERIFICATION   DEMOBILIZE
REVIEW   →   PREPARATION   →   OPERATIONS   →   AND TESTING   →   GROUTING

■ Abandon/Extend   ■ In Situ Waste
   Existing Wells   Treatment
■ Prepare Borrow Sites ■ In Situ Subsidence
                            Control
■ Initial Site Grading
                         ■ Ex Situ Treatment
                            of Pad A Wastes

                                              BEGIN SITE   CONSTRUCT
                                              GRADING   →   CAP

                                                                  ■ Gas Management
                                                                  ■ Cap Section
                                                                  ■ Surface Water Control

Figure 3-16. In Situ Grouting alternative schematic.

In this alternative, grout would be pumped into the waste zone under high pressure using an injection lance. The injection lance would be inserted into the waste zone using rotary percussion hydraulic hammers, which are commonly used on rock coring drill rigs. To minimize the potential for contamination spread, the lance is direct-driven into waste, so no cuttings or drilling fluids are generated. However, even with this technique small amounts of contamination are expected to be brought to the surface, adhered to the injection lance, or contained in grout returns, which could pose a hazard to workers. Therefore, the grouting rig would be operated inside of a confinement building and workers would be distanced from the equipment during operations. Figure 3-17 offers a conceptual illustration of the grouting operation.

The drill mast, hydraulic head, and injection lance can be mounted on various platforms (e.g., trucks, skids, or tracks). Detailed engineering studies have not been completed to select the best platform(s). Past work at the INEEL used a track-mounted unit, but other platforms offer advantages. For this analysis, the primary deployment platform is a wheeled gantry crane (Armstrong, Arrenholz, and Weidner 2002). The wheeled gantry crane allows easier movement of the rig from hole to hole and distances workers from the equipment while in operation or during moves (Loomis 2001).

In addition to risk posed to workers during operations, there is also risk of surface contamination spread after grouting is completed. If contaminated grout is deposited on the ground surface during operations, it would become exposed to the elements after the temporary confinement building is removed. Wind and weathering could cause contaminants to become airborne, which would pose a risk to nearby facilities. Grouted areas would be covered with a 3-ft layer of soil after operations before moving the confinement building to mitigate potential contamination concerns associated with grout returns.
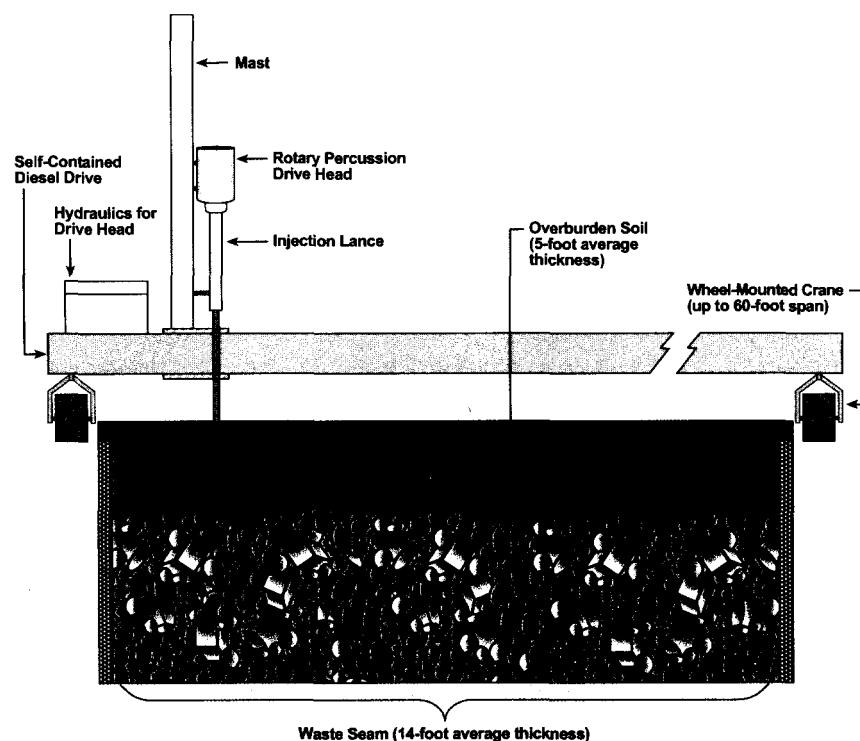
Figure 3-17. Schematic of an in situ grouting operation.

The injection lance would be repeatedly inserted in a tightly spaced pattern. The injection method would produce interlocking columns of grout extending from the underburden soil up through the waste, terminating belowgrade in the overburden. Past work has demonstrated that the interlocking columns cure into a solid monolith with no discernable edges between columns (Armstrong, Arrenholz, and Weidner 2002). Using dense injection spacing also ensures that containers (drums) of waste are punctured by the lance and filled with grout. When injected under high pressure, the cutting action of the grout fractures soil, plastic, wood, and other low strength objects. The cutting action of the jets dislodges particles and small pieces of waste material and mixes them with grout and soil. Large objects remain in place as grout flows under pressure, filling all readily accessible voids between objects (Loomis, Zdinak and Bishop 1997).

When properly designed and applied, ISG produces a durable waste form that resists weathering and degradation over long periods of time. Grout waste forms have been shown to be effective at minimizing infiltration of water and reducing contaminant release to the environment. The supporting report by Armstrong, Arrenholz, and Weidner (2002) provides a discussion of contaminant release. In situ grouting reduces mobility of contaminants by the following mechanisms:

• Reduced permeability—Injecting grout under high pressures into the disposal area fills void space around debris and in the soil matrix. Properly spaced injection points rupture waste containers and fill void spaces inside waste drums and boxes with injected grout. The resultant grout and waste monolith has a very low porosity and low hydraulic conductivity.

• Physical stabilization—Significantly reduced void space in the waste and soil matrix prevents future compaction and subsidence of waste, thereby providing a stable foundation for durable cover systems.

- Encapsulation—Energetic mixing of grout, waste, and soil encases contaminants in a leach-resistant matrix. This minimizes the potential for contaminants to be mobilized by infiltrating water.

- Chemical stabilization—An appropriately selected grout will chemically alter infiltrating water to reduce the solubility potential of contaminants. In addition, certain grouts exhibit an affinity for specific contaminants and can chemically bind contaminants by reaction or adsorption to reduce leachability.

Grouted waste forms are highly durable and will remain physically and chemically stable for long periods of time. Because the grout monolith is constructed 4 to 5 ft bgs, it is protected from mechanical forces (e.g., freeze-thaw cycles). Using selected grouts that are in chemical equilibrium with the site-specific geochemistry also minimizes degrading chemical forces. While some cracking is expected as grout cures, contaminant releases would still be controlled by chemical properties of grout. The grouted waste form would degrade slowly over time. However, because the grout materials are highly insoluble, it is estimated that under the worst conditions, extremely long periods of time would be required for infiltrating water to degrade the waste form (Armstrong, Arrenholz, and Weidner 2002).

Because ISG has only been applied on small scale sites, actual production rates are unavailable. For this evaluation, production rates were estimated based on results of field tests, which are described in more detail in Section 4. The majority of the area that would be treated by grout is in the TRU pits and trenches, which comprises a total of approximately 17 acres. Figure 3-18 presents the estimated operational time for individual waste areas within the SDA. The operational time assumes a single grout rig with a 40-hour work week and does not include pregrouting activities (e.g., design) or postgrouting activities (e.g., capping). As shown, a single rig would require approximately 15 years of operation to accomplish the grout remedial action within the SDA.

3.8.1.1 Organic Pretreatment.
As discussed in Section 2, one dominant waste type in the SDA consists of contaminated oil and other hazardous chemicals that were solidified with an absorbent, packaged in drums, and disposed of at the SDA. In anticipation of the need to treat this particular waste stream, some testing has been performed to demonstrate the ability of grout to treat organic waste. In bench and field tests, a number of grout products have been shown to effectively treat oil waste at approximately a 10% waste loading (Armstrong, Arrenholz, and Weidner 2002). As a result, it has been concluded that ISG would effectively treat isolated occurrences of organic oil waste drums across the SDA pits. However, disposal records clearly show that several small areas within the SDA received large shipments of this waste and may still contain concentrations exceeding 10%. Figure 3-9 illustrates several small areas, totaling less than 1 acre, which may contain large caches of drums containing organic oil. Because ISG has not yet been tested for waste at these concentrations, it is assumed that pretreatment would be required.

ISG Planning	
Site	Implementation Time
Pits 1-6 & 9-12	11 years
SVRs	0.3 years
Trenches 1-10	1.5 years
Additional trench areas for COCs	0.2 years
Additional foundation stabilization	2 years
TOTALS	15 years

Figure 3-18. In situ production.

The ISTD technology would be used to destroy organic oil in these areas. This process would be followed by ISG to stabilize remaining contaminants. ISTD places electric heating elements into waste on approximately 2.4-m (8-ft) centers to heat the waste zone to a temperature sufficient to pyrolize and

volatilize most organic material over a several month period. Without this step, grout might not harden and successfully immobilize waste.

3.8.1.2 ***Pad A Waste.*** Another problematic waste stream for ISG is nitrate salt. This salt is a dry, granular form that was drummed and disposed of throughout the SDA. As with organic waste, some testing has been done to demonstrate the ability of grouting to effectively treat nitrate salt. In some tests, waste loading as high as 50% nitrate salt has been achieved without deleterious effects (Armstrong, Arrenholz, and Weidner 2002). It is expected that drums of nitrate salt mixed with other waste in the SDA pits will not pose a problem for ISG. However, over 70% of all waste on Pad A, nearly 7,600 m³ (10,000 yd³), is evaporator salt consisting of approximately 60% sodium nitrate, 30% potassium nitrate, and 10% other compounds (DOE 1994). Without further testing, it is uncertain ISG would be successful with such high concentrations of nitrates as found on Pad A. Therefore, the assumption for this evaluation is that Pad A waste would be retrieved and its waste streams segregated and stabilized in an ex situ treatment process. The treated material would then be disposed of back onsite beneath the proposed cap.

3.8.2   In Situ Vitrification Alternative Description

The ISV technology has been implemented at a number of waste sites around the world. An evaluation of this technology's applicability to the SDA, including a summary of four recent ISV case histories, is provided in the comprehensive report developed for this analysis (Thomas and Treat 2002). Figure 3-19 shows individual components of ISV for WAG 7 along with the sequence of processing steps in the ISV operation. As shown in Figure 3-19, before the TRU waste units at the SDA are vitrified, they would be pretreated using ISTD to remove most of the water, any other liquids, and VOCs. Pretreating waste using ISTD would be necessary to preclude the potential for a steam explosion that might otherwise breach the approximately 3-m (10-ft) soil cover maintained over the melt during active ISV processing. Pretreatment with ISTD also would be more likely to cause slow venting of acetylene and other flammable gases that may be present in gas cylinders disposed of in the SDA, thereby precluding an explosion or uncontrolled fire in the off-gas hood. A Modified RCRA Subtitle C cap would then be constructed over the site to provide additional protection by limiting infiltration and preventing intrusion of plant roots and animals into soil containing condensed SVOCs. As with the preceding alternatives, long-term monitoring of the site, including groundwater, would be conducted to verify effectiveness.
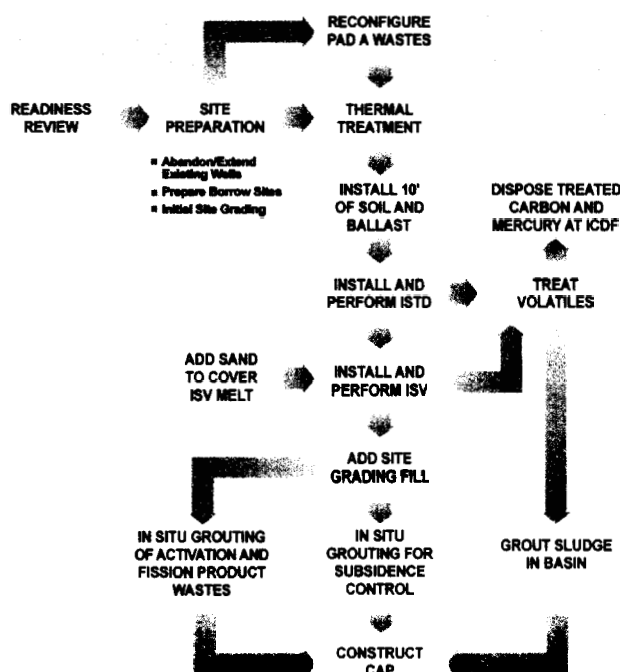
Figure 3-19. In Situ Vitrification alternative schematic.

Heat generated by ISV converts (vitrifies) buried waste and associated soil into a glass-like substance at temperatures ranging from about 1,200 to 1,600°C. Most nonmetallic, inorganic materials (e.g., soil and sludge) will melt and subsequently solidify into a largely amorphous material similar to

obsidian. Most of the metallic materials will also melt, but remain as metals, and sink to the bottom of the glassy melt because they are denser than glass. The ISV technology offers several advantages:

- Ability to process a wide range of waste types

- Ability to pyrolyze organic materials, thereby destroying them

- Ability to immobilize waste in a highly leach-resistant and durable form.

Traditional ISV employs an array of four electrodes placed vertically into buried waste and contaminated soil. Electrical current is transferred through the soil between the electrodes, generating heat as a consequence of the soil's resistance to the flow of current. Graphite powder or other electrically conductive materials are placed between the electrodes to provide a starter path for initiating the flow of current. As heated soil and waste melts, electrodes progressively drop through the melt, resulting in the melt growing downward and widening in the process. The progression of a typical ISV melt is presented in Figure 3-20.
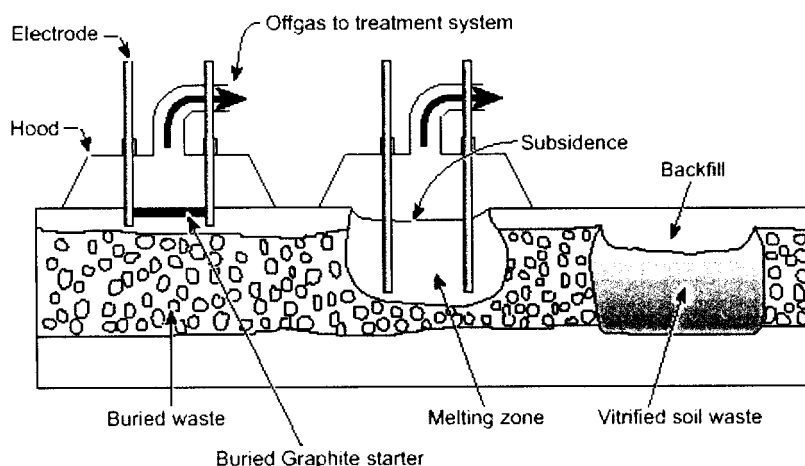

Figure 3-20. In situ vitrification melt progression.

Holding electrodes in place or stopping the flow of current can be used to control melt depths. As size of the melt increases, cooling surface area also increases, until energy lost to cooling equals the amount input by electrodes, thereby stopping further growth of melt. When melt has progressed to a final depth, power is stopped and the melt is allowed to cool. Cooling the melt to ambient ground temperatures requires several years because of insulating properties of soil.

Most organic materials within soil and waste are pyrolyzed or volatilized, then collected and treated in an off-gas treatment system. An off-gas hood covers the entire melt, extending some distance around its edge to control the removal of gases and airborne particles. Off-gases are drawn into the off-gas hood and then treated through a process train consisting of several treatment operations before cleaned gas is discharged to the atmosphere.

Full-scale melts have ranged from 200 to 1,400 tons and generally require approximately 10 to 14 days to complete. The greatest melt depth achieved with the traditional ISV configuration shown in Figure 3-19 was 6.7 m (22 ft). Final melt diameters have ranged up to 13.7 m (45 ft). Generally, when a melt is completed, electrodes are left in the molten glass and sawed off at ground surface. The final melt is smaller than the volume of waste treated as a result of the increased density of glass relative to waste and soil, and removal of gases and void space. Volume of waste is reduced 30 to 70%.

Subsurface planar ISV, a recent advancement of the traditional ISV technology, is being evaluated for the SDA. This modified approach differs from the traditional ISV approach in the method of applying the electrical current and the depth of the soil at which the flow of current is initiated. In subsurface planar ISV, electrical current is transferred only between pairs of electrodes, rather than among all four electrodes, causing two planar-shaped melts to form. As the melts grow downward and spread, they eventually meet and fuse together into a single melt. The starter path for electrical current in the subsurface approach is either installed as a wet or dry material in a deep trench, or injected as a slurry at the desired starting depth. A layer of unmelted soil is maintained at all times over the molten mass, in contrast to the traditional approach in which molten material is exposed at the ground surface.

ISV Planning		
Site	Melts	System Years
Pit 1	33	2
Pit 2	104	7
Pit 3	56	4
Pit 4	150	11
Pit 5	146	11
Pit 6	74	5
Pit 9	61	4
Pit 10	150	10
Pit 11	33	2
Pit 12	40	3
Pad A	47	3
Trenches 1-10	406	29
TOTALS	1,300	91

Figure 3-21. ISV production requirements.

Subsurface planar ISV tests have been successfully initiated between 1.8 and 3 m (6 and 10 ft) bgs in cold and hot tests conducted in Richland, Washington, for the INEEL in 1998, and at Los Alamos National Laboratory in 1999 and 2000. Melts progressed downward from these starting depths, reaching a maximum depth of about 7.6 m (25 ft). Subsurface planar ISV offers several primary benefits:

- Lowered temperatures within the off-gas hood because overburden effectively insulates the hood from the melt surface

- Improved melting energy efficiency and increased potential for greater melting depths because insulation over the melt surface conserves more heat for melting

- Enhanced protection of equipment and personnel from molten glass expulsions because overburden provides a protective physical barrier against these events.

A disadvantage of subsurface planar ISV is the likelihood that SVOCs would condense in the overburden soil. These contaminants would otherwise volatilize from the open melt and be collected and processed in the off-gas treatment system.

Waste units at the SDA that would be treated with ISV include Pits 1 through 6, Pits 9 through 12, Trenches 1 through 10, and Pad A. These sites comprise a total area of approximately 17 acres. The areal extent of the vitrified zone would be about 20% larger because ISV melts would extend into adjacent soil to some extent. This especially would be the case for narrow buried waste trenches, where a single line of contiguous ISV melts would vitrify more adjacent soil per unit volume of waste treated than would the numerous adjoining rows of melts used to treat pits. Retrieving and staging Pad A waste in a subsurface pit as required for safe and effective treatment would also increase the total area to be vitrified.

Multiple ISV systems could be operated concurrently. As shown in the ISV plan presented in Figure 3-21, approximately 91 system years would be required to treat the specified waste zones within the SDA. One system year represents the average waste area that can be processed by one ISV system in one year. Thus, six ISV systems would be required to complete ISV operations in 15 years.

3.8.2.1 Pretreatment. Waste would be preconditioned with ISTD before application of ISV. Like ISV, ISTD heats waste but at slower rates and to lower temperatures. Preconditioning waste before ISV is needed to preclude the risk of high-energy melt expulsion events. In addition, pretreatment provides a concentrated off-gas stream that is more amenable to treatment than the highly diluted off-gas stream produced in the ISV process. Concentrated gases are easier to treat because longer residence times can be achieved in equivalent-size unit treatment processes, resulting in improved reactions and physical separations. The process also is much more energy-efficient because dilution air does not have to be heated, cooled, or exhausted.

In a melt expulsion event, molten glass propelled by releasing pressurized gas within the melt is blown into the air. The source of pressurized gas may be an explosion or a rapid conversion of water to steam. The force of expulsion may cause damage to the off-gas hood and contaminated gases to be released to the environment. During ISV, melt expulsion events occur because molten glass is an incompressible fluid that prevents the dissipation of pressurized gas into the void space of surrounding unmelted soil and waste. During ISTD, the release of the gas would occur without the potential for melt expulsion events, because waste contains substantial interconnected porosity and is not molten. The interconnected porosity of unmelted waste and soil allows steam and other gases rapidly released below the ground surface to safely compress into the interconnected void space and then migrate toward the ISTD gas extraction pipes.

The ISV off-gas stream would be more difficult to treat than the ISTD stream because it would be diluted with 100 parts of air to 1 part of gas generated within the waste zone to ensure that concentrations of combustible gases do not rise above their lower flammability limits.

3.8.2.2 Grouting. For this alternative, ISV would not be implemented in the SVRs or the non-TRU trenches. The assumption for this alternative is that ISG would be implemented in these areas as described in Section 3.3.4. Foundation grouting would also be applied in the remaining SDA areas to prevent subsidence of the cap, as discussed in Section 3.3.3.3.

3.8.3 Evaluation of In Situ Treatment Alternatives

The two in situ treatment alternatives are compared against the initial screening criteria of effectiveness, implementability, and cost in the following sections.

3.8.3.1 Effectiveness. The ISV and ISG alternatives, as assembled, are effective in mitigating the long-term risks associated with identified COCs at the SDA. Both alternatives include the Modified RCRA Subtitle C cap system to hydraulically isolate the treated waste, and both would reduce the leachability of the COCs through direct treatment. Fate and transport modeling conducted for each of the alternatives shows that release rates for each COC will be reduced to levels that protect human health and the environment. Results of the modeling are summarized in Section 4.

With the placement of the engineered cap, soil temperature and humidity will be maintained at a virtually constant level within the treated waste zone, and the area freeze/thaw and wet/dry cycles will not affect buried grout and glass monoliths. For ISV, the *Technology Screening Guide to Radioactively Contaminated Sites* (EPA 1996) states "the vitrified mass is very resilient to weathering, which makes it effective for long-term containment of waste." Similarly, grout waste forms, when designed to be compatible with the geochemical environment, will last indefinitely without significant chemical or physical alteration. In the SDA environment, where any infiltrating water will be nearly saturated with minerals, dissolution of grout minerals is expected to occur at an extremely slow rate.

The advantage of ISV is that it pyrolyzes, evaporates, and extracts nearly all organic material within the melt zone, thereby reducing the overall mass of contaminants remaining in the SDA. However,

some contaminants would remain in the metal phase that sinks to the base of the glass melt, and others would likely condense in the surrounding soil to some extent. The metal phases at the base of the melts would corrode at a faster rate than glass, thereby increasing the leach-potential of some contaminants. Additional testing may be required to assess the fate of specific mobile contaminants of concern (e.g., C-14 and uranium) that may be largely incorporated in the more corrosion-prone metal phase. An extensive testing program was advocated in the engineering report that accompanies this analysis (Thomas and Treat 2002). Testing could address factors such as the fraction of C-14 and uranium that remains in the metal phase, leachability of the metal phase, and potential for glass melt to act as a barrier that limits contact of the metal phase with water.

Metallic waste forms (e.g., irradiated steels) would be more effectively immobilized in the ISG alternative because of the more basic chemical environment (higher pH) created by the grout. The higher pH environment reduces solubility of most heavy metal species. Grout could not be injected to encapsulate the metallic zone in ISV melts because metals would be in contact with the glassy phase and probably basalt that underlies the waste zone. Thus, with ISV, lead and other hazardous metals may dissolve more readily, because of the neutral chemical environment of glass.

As described in the supporting report (Armstrong, Arrenholz, and Weidner 2002), ISG has been shown to effectively immobilize a wide range of contaminants, including RCRA metals and radioactive isotopes. Testing of commercially available grout has shown that VOCs can also be effectively treated at low concentrations. Specialized grout forms have been developed and demonstrated by DOE to immobilize nitrate waste at up to 50 wt% waste loading. Because not all COCs have available performance data, some uncertainty exists. However, the relatively low permeability of grout, combined with its beneficial chemical properties, indicates that contaminants could be immobilized for a long period of time.

Short-term effectiveness of either ISG or ISV is moderate. Both alternatives have been researched for application at the SDA, and their potential risks to workers, the public, and the environment have been identified. The bases for selecting technologies to form these alternatives included the need to minimize these risks and ensure long-term effectiveness. Short-term risks associated with implementing ISG alone are relatively low. They include high pressures required for grout injection and potential for contaminated grout to spill onto the ground surface. Adding ISTD to the ISG alternative to address uncertainties associated with high concentrations of organic material in waste could diminish the short-term effectiveness of this alternative. Specifically, applying ISTD would increase risks of surface and subsurface fire, explosion, and airborne contamination.

Risks associated with ISV include those described above for ISG and ISTD because these technologies are included as components of the alternative. Additional risks of the ISV alternative include melt expulsion events, thermal and electrical hazards, and risks involving frequent handling of heavy equipment.

Appropriate design features and engineering and administrative controls would be applied in both alternatives to ensure adequate short-term protection to workers, the public, and the environment. However, additional study of both alternatives is necessary to further identify specific design and operating requirements to achieve short-term effectiveness goals.

3.8.3.2   *Implementability.* Both alternatives are implementable at the SDA. Summaries of case studies and performance data are provided in the supporting reports (Armstrong, Arrenholz, and Weidner 2002; Thomas and Treat 2002). Equipment for both alternatives is either currently available or can be manufactured to satisfy remedial action needs. For ISV, the presence of concentrated levels of fissile materials, irradiated fuel material, gas cylinders, reactive oxidizers, and flammable liquids, and the

lack of knowledge of their precise locations within the SDA, complicates implementation of the alternative. Expensive design features and controls would be required to ensure short-term effectiveness.

Though site-specific applications of ISG and ISV at the SDA have been researched in nonradioactive bench-scale and field-scale tests, many issues have not yet been addressed. Both alternatives would require more detailed evaluation of waste generation and disposal records, additional site sampling and analysis, and nonradioactive and radioactive remedial design testing to define specific requirements. For ISV, a method of maintaining at least a 3-m (10-ft) thick soil cover over the melt that avoids bridging and allows for the safe release of gases generated within the melts also must be developed. Risk of unsuccessful development and resolution of safety issues is much higher for the ISV alternative.

It is estimated that up to 700 kW of power will be required to implement the ISV technology with approximately 330 kW required for ISTD. Currently, the Pit 9 substation at the SDA has one line that can provide 15 MW of power. However, for implementation of this alternative, it is assumed that the construction of a project-specific substation will be required.

3.8.3.3   Cost. Table 3-4 summarizes the initial cost estimate and comparative evaluation performed for the two in situ treatment alternatives.

Table 3-4. Total estimated costs for the In Situ Grouting and In Situ Vitrification alternatives.

Cost Element (FY 2002 dollars)	In Situ Grouting ($M)	In Situ Vitrification ($M)
Capital costs	1,073	1,785
Operating and maintenance costs	46	30

As shown, the capital cost for implementing ISV is more than 50% greater than the estimated capital cost of ISG. Capital costs for both alternatives have a number of common elements including constructing the final cover system and implementing ISG in the SVRs and non-TRU trenches. The primary cost differential is associated with technology requirements for treating TRU pits and trenches and the more extensive use of ISTD as a pretreatment for the ISV alternative.

3.9   Retrieval, Treatment, and Disposal Alternative

3.9.1   Alternative Description

The RTD alternative addresses RAOs by retrieving, treating, and disposing of RFP TRU waste. The alternative includes treating retrieved waste, as required to achieve ARARs and facility-specific WAC for either onsite or off-Site disposal. In this alternative, all retrieved TRU waste will be disposed of at the WIPP facility in Carlsbad, New Mexico. All retrieved MLLW will be treated for hazardous constituents and returned to the SDA for disposal in an engineered facility along with any retrieved LLW. A schematic drawing showing individual elements of the alternative is presented in Figure 3-22. As shown, the alternative includes an in situ pretreatment for the high VOC waste and in situ treatment of activation and fission product waste using ISG. This alternative also includes placing a low-permeability cap over the entire SDA to prevent future biotic intrusion into remaining waste or contaminated soil.
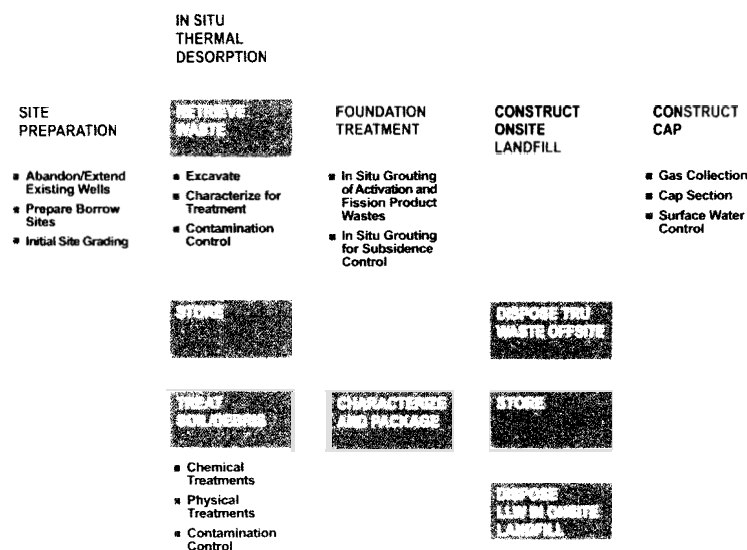
Figure 3-22. Retrieval, Treatment, and Disposal alternative schematic.

As discussed in Section 3.1, retrieval actions will specifically target disposal sites containing the RFP TRU waste in Pits 1 through 6, Pits 9 through 12, Trenches 1 through 10, and Pad A. For this analysis, retrieval requirements were assumed to include waste and soil extending to the first basalt flow. Estimated volume of the SDA soil and waste to be retrieved is based on the available waste inventory. All interstitial soil, 1 ft of the overburden, and 1 ft of underburden soil in each of the disposal units are assumed contaminated above remediation goals. A summary of estimated retrieval volumes is presented in Figures 3-3 and 3-4. For this initial screening evaluation it is assumed that approximately 50% of the RFP waste streams will be classified as TRU waste, with the remainder classified as either LLW or MLLW. This assumption results in these retrieval projections:

- 55,800 m^3 (73,000 yd^3) of TRU waste and soil

- 174,000 m^3 (228,000 yd^3) of MLLW, LLW, and soil.

In addition to the primary remedial action, which involves retrieval, ex situ treatment, and disposal of this waste and soil, it is assumed that implementing this alternative would require the following supplemental remedial actions:

- Activation and fission product treatment—Given the lack of available disposal facilities and concerns regarding retrieving and managing remote-handled waste from SVRs and trenches, activation and fission product waste streams containing COCs in these areas (as shown in Figure 3-5) will be treated in place with the ISG technology.

- Treating VOCs—High organic areas within the SDA (see Figure 3-9) would be treated with ISTD before retrieval to minimize VOC management and contaminant control requirements during retrieval.

- Cap construction and foundation stabilization—This alternative includes backfilling excavated areas to return the site to grade before placing a low-permeability, long-term cover over the SDA. The modified RCRA Subtitle C cover would be placed over the SDA to provide additional protection and to minimize future groundwater impacts resulting from leaching of any remaining residual contamination. Backfill materials will be compacted as required to support the cover system. In addition, any remaining untreated waste units will be stabilized using the ISG technology before constructing the cover as discussed in Section 3.3.3.

The alternative consists of three basic GRAs—retrieval, ex situ treatment, and disposal. Each of these actions is briefly described in following subsections.

3.9.1.1 Retrieval.
A number of previous retrieval actions have been conducted for buried waste within the SDA. These include the Early Waste Retrieval project, implemented in 1974, and the Initial Drum Retrieval project, completed in 1978. The Early Waste Retrieval project was implemented to retrieve the oldest buried waste at the SDA (which is in Pits 1 and 2). For both projects, standard earthwork equipment (scrapers and excavators) and manual labor were used to remove overburden soil. Waste containers were removed with vertical lift slings attached to the bucket of a backhoe, and all loose waste and interstitial soil were generally removed by hand or shovel. For the initial drum retrieval, an air-supported weather shield was placed over the work area. All retrieval actions for the EWR were performed inside of an operating area confinement, which was a self-supporting metal building constructed of lightweight metal panels. Exhausted air was filtered through HEPA filters. The primary conclusion from these past retrieval actions is that retrieving buried waste from the SDA is possible. However, to implement full-scale retrieval within the SDA, further development of specific technologies and process options will be required.

For the RTD alternative to be successful, careful consideration must be given to protecting workers, the public, and the environment. Several technologies and controls would be used in order to provide this protection:

- All retrieval activities would be conducted within a double containment structure. A ventilation system would be incorporated into the primary containment structure.

- Excavation sizing, and sorting would be performed by operators wearing personal protective equipment and using manually operated construction equipment with sealed and pressurized cabins.

- Monitoring at the excavation (digface) would be performed to determine external radiation levels; these levels would then be used to determine appropriate measures to protect equipment operators and maintenance personnel.

- Using shoring and soldier piles may require sealing to prevent source release inside the primary containment.

The PERA adopts the assumption that waste retrieval operations can be designed to provide a production rate of 76 m³ (100 yd³) per day. This production rate was determined through an evaluation of retrieval equipment, cold tests, previous SDA retrievals, retrieval actions in the United States and Australia, treatment throughputs, storage capacity, and disposal facility rates of waste acceptance. It is assumed that retrieval operations would be conducted 200 working days a year, and that crews would work four 10-hour shifts each week. An estimate of the production requirements for specific SDA disposal units is provided in Figure 3-23.

During retrieval, several types of contamination control would be practiced. Metal curtains would be used to segregate highly contaminated portions of the digface from relatively uncontaminated areas. Foggers, sprays, misters, fixatives, and washes would be used to create a barrier between the work surface and the atmosphere; fix loose, airborne and settled contamination to a surface; and decontaminate personnel, atmosphere, or the environment. For treating and packaging, the entire process would take place in a waste treatment facility specifically designed for proper contamination control. Facility features would include airlocks, multiple contamination control zones, cascading ventilation systems, multiple HEPA filtration on building and process exhaust streams, and continuous monitoring of emissions.

The initial operation at an individual waste unit would involve removing clean overburden soil, which would be stockpiled in an adjacent on-site area. Following retrieval of waste, the waste unit would be backfilled with the stockpiled soil augmented as required with clean soil from an approved off-Site borrow source. Retrieval would then commence at a different pit or trench, and the process would be continued until designated waste was retrieved and the units backfilled.

Retrieval Planning	
Site	Years
Pit 1	0.5
Pit 2	1.5
Pit 3	0.8
Pit 4	2.1
Pit 5	2.1
Pit 6	1.1
Pit 9	0.9
Pit 10	2.1
Pit 11	0.5
Pit 12	0.6
Pad A	1.4
Trenches 1-10	1.5
TOTALS	**15.1**

Figure 3-23. Retrieval production requirements.

3.9.1.2 *Ex Situ Treatment.* Retrieved materials would be treated as necessary to meet health-based standards, regulatory requirements, and the WAC for specific disposal facilities. These treatments would include chemical, physical, and thermal treatment. Some TRU waste would require sizing. All waste and soil would be characterized and assayed to meet transportation requirements and WIPP WAC. Some treatment is expected to be required for the TRU waste fraction. Treatments include solidification of free liquids, removal of prohibited items, and eliminating corrosive, flammable, or reactive hazardous characteristic properties.

Retrieved MLLW and contaminated soil would require treatment before being permanently disposed of. Treatment can include physical treatments (e.g., shredding, sizing, and sorting), thermal treatment (e.g., steam reforming) for removing and destroying hazardous organics, and stabilization to fixate regulated metals. These actions would be performed under a negative pressure in the waste treatment facility, which would be equipped with scrubbers and HEPA filters for off-gas emissions to protect workers and the environment. Characterization of the material would be performed during and following treatment to ensure the treated waste meets the WAC for the disposal site and to determine health and safety requirements (e.g., PPE and air monitoring requirements).

3.9.1.3 *Disposal.* The only certified and permitted facility for disposal of retrieved TRU waste, including TRU-contaminated soil, is the WIPP. Onsite disposal of TRU waste was not considered implementable because of regulatory issues associated with potential ARARs, which could dictate specific treatment standards and design requirements for an onsite TRU waste disposal facility. Furthermore, a facility used for the disposal of TRU waste would have to be designed to meet the geologic repository performance objectives of 40 CFR 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes."

For the disposal of retrieved LLW and MLLW, which will be treated to satisfy ARARs, the RTD alternative requires constructing an onsite, engineered facility. In accordance with projected ARARs,

design elements consistent with the construction standards for a RCRA Subtitle C facility would be required. Specific requirements would include a double membrane subgrade liner with leachate detection and a fine-grained multilayer surface barrier. As discussed in Section 2, the design developed for ICDF landfill would be appropriate for application within the SDA and was identified as the representative technology.

Though construction of a new, engineered facility at the RWMC was identified as the process option for this alternative, available on-Site and off-Site facilities also could be considered during final design for disposal of a portion of the projected waste. The ICDF landfill, which will be located near INTEC, will be ready to accept CERCLA LLW and MLLW in 2003 (DOE-ID 2002). As noted in Section 2, several off-Site facilities are available to receive LLW and MLLW, including Envirocare in Utah and U.S. Ecology in Washington. The Barnwell site in South Carolina is also available, but its east coast location makes it logistically less desirable. Each facility has specific WAC that must be met before disposal.

3.9.2   Evaluation of the Retrieval, Treatment, and Disposal Alternative

3.9.2.1   Effectiveness. Retrieving and disposing of SDA soil and buried waste in accordance with each of the three GRAs would be effective in achieving RAOs and protecting human health and the environment. However, implementing the retrieval action itself has the potential to impact human health and the environment.

Transuranic radioisotopes pose a health risk when inhaled or ingested. In addition, cancer resulting from the ionizing radiation is of concern. Retrieval equipment, vacuums, containment structures, and other standard construction equipment and facilities are proven and reliable in radioactive and hazardous environments. The technologies for waste processing and treatment, while proven, may require modification to improve confinement.

Off-Site disposal also poses a number of issues. Large volumes of contaminated material across the country are directly proportional to projected short-term transportation risk. Preliminary estimates are that over 7,000 truckloads would be required for off-Site disposal of RFP waste (assuming 50% of the RFP waste streams were to be classified as TRU). The likelihood of accidents outside of the INEEL increases with each loaded vehicle traveling to an off-Site destination. However, the shipping containers for transuranic waste have been demonstrated by the Nuclear Regulatory Commission to withstand extreme accident conditions without breaking open or releasing radiation, and it is highly unlikely that radioactivity would be released, even in the event of an accident.

3.9.2.2   Implementability. The implementability of a large-scale retrieval action at the SDA would be difficult because a transuranic waste retrieval project of this magnitude has not yet been performed. Consequently, some actions required to implement alternatives may be the first of their kind and require site-specific designs. Such designs must address and account for a number of health and safety issues to ensure safety of workers and prevent any uncontrolled release of contaminants to the environment. However, most of the technologies—containment structures, material handling facilities, transport facilities, characterization technologies, and ex situ treatment technologies—are implementable at the SDA.

A second key issue regarding implementability of a retrieval action targets availability of necessary equipment and skilled workers. Given the nature of waste and site conditions, equipment required for a retrieval action would most likely have to be modified specifically for this project. Examples of necessary equipment include remote devices, containment structures, ventilation systems, contamination control

devices, treatment units, and packaging facilities. Workers required to implement this alternative are available in eastern Idaho, but they would need specific training.

An important implementability concern for off-Site disposal of TRU waste is the magnitude of the transportation requirements. The over 7,000 truckloads projected for the off-Site disposal requirements would have an impact on roads and communities adjacent to the INEEL.

For onsite disposal, implementability issues revolve around regulatory concerns that would dictate specific treatment standards and design requirements for onsite storage.

3.9.2.3   Cost. Costs for a full-scale retrieval action at the SDA are very high compared to those of either the Containment or the In Situ Treatment alternatives discussed previously. Table 3-5 provides a summary of the costs for this alternative.

Table 3-5. Total estimated costs for the Retrieval Treatment, and Disposal alternative.

Cost Element (FY 2002 dollars)	Cost| ($M)
Capital costs	6,859
Operating and maintenance costs	30

3.10   Summary of Preliminary Screening Results

A comparative screening summary of each of the alternative's effectiveness, implementability, and cost is provided in Figure 3-24. Those alternatives retained for detailed analysis in Section 4 also are identified.

In accordance with EPA guidance, the No Action alternative, though not protective, is retained for comparative purposes as the base alternative for the detailed evaluations presented in Section 4.

The Limited Action alternative does not achieve the proposed RAOs and therefore has not been retained for detailed analysis. The alternative will only deter human exposure to the identified COCs, depending solely on long-term institutional controls to prevent future access to waste sites and area groundwater. The alternative also does not reduce toxicity, mobility, or volume of site contaminants. Further, the alternative does not prevent or inhibit future migration of contaminants from the source term to the underlying groundwater.

The Surface Barrier alternative was retained for detailed analysis. Constructing the surface barrier does not require extensive intrusive work, and risks resulting from potential worker exposure and environmental releases during implementation are relatively low. In addition, preliminary fate and transport modeling indicates that the cap, with selective application of the ISG technology, would meet the RAOs and provide long-term protection of human health and the environment.

Alternatives	Effectiveness	Implementability	Costs	Retained?
No Action	• Does not mitigate site risks	• Maintenance of existing monitoring programs only	• No capital costs • Long term monitoring costs only	Yes - In accordance with EPA directive
Limited Action	• Prevents direct exposure • Does not treat source • Does not mitigate projected groundwater impacts	• Standard earthwork • Does not require intrusion into the waste • Requires future groundwater use restrictions	• Low capital costs • Long term monitoring and maintenance costs	No - Does not achieve RAOs
Surface Barrier	• Prevents direct exposure • Surface Barrier reduces contaminant mobility and minimizes groundwater impacts • Does not reduce toxicity or volume of source • Activation/fission products in SVRs and trenches stabilized with ISG • VOCs in high organic waste streams destroyed with ISTD	• Short implementation period • Standard earthwork • Minor amount of intrusive work • 5M cy of material required for construction	• Capital costs significantly higher than Limited Action • Long term monitoring and maintenance costs	Yes - Achieves RAOs with lowest capital costs
Full Containment	• Prevents direct exposure • Reduction in contaminant mobility similar to surface barrier • Activation/fission products in SVRs and trenches stabilized with ISG • VOCs in high organic waste streams destroyed with ISTD	• Longer implementation period • Requires major extensive intrusive work • Implementation verification difficult	• Capital costs significantly higher than surface barrier • Similar long term monitoring and maintenance costs	No - Minor degree of additional protectiveness does not offset concerns associated with implementability, short term worker exposure and higher costs
In Situ Grouting	• Prevents direct exposure • Reduces contaminant mobility through treatment • Long term stability of grouted matrix • VOCs in high organic waste streams destroyed with ISTD	• Researched for INEEL specific application • Long implementation period • Requires extensive intrusive work • Requires the implementation of ISTD technology to pretreat high organics areas	• Capital costs higher than Surface Barrier • Long term monitoring and maintenance costs	Yes - Alternative meets RAOs and provides for a further reduction in containment mobility
In Situ Vitrification	• Prevents direct exposure • Reduces contaminant toxicity, mobility, and volume through treatment • Provides a more stable long term matrix • Activation/fission products in SVRs and trenches stabilized with ISG	• Specialized equipment required • Long implementation period • Concerns associated with potential worker exposure and contaminant release during implementation • Requires implementation of ISTD technology to pretreat wastes • Site-specific technology applications must be proven	• Capital costs higher than ISG • Long term monitoring and maintenance costs could be reduced	Yes - Alternative meets RAOs and provides for improved stability of waste form
Retrieval/ Treatment/ Disposal	• Prevents long term direct exposure • Highest potential short term exposures • Reduces contaminant toxicity, mobility, and volume through treatment • Removes all TRU wastes from source areas • Activation/fission products in SVRs and trenches stabilized with ISG	• Very long implementation period • Requires specialized contamination control/retrieval equipment • Regulatory concerns associated with off-site disposal of TRU wastes • Site-specific technology applications must be proven	• Highest capital costs associated with contamination control/retrieval equipment, characterization, and treatmen • Long term monitoring and maintenance costs can be minimized	Yes - Alternative meets RAOs by removing buried TRU waste

Figure 3-24. Initial screening summary.

The Full Containment alternative was not retained for detailed analysis. The incremental increase in long-term protectiveness offered by this alternative was considered to be relatively small and does not appear to warrant the significant projected increase in remedial costs. The increased effectiveness of a horizontal barrier is questionable because permeability of the horizontal barrier would probably be significantly greater than that of the surface barrier. In addition, implementing this full containment alternative will require significant intrusive activities, which will heighten potential worker exposure concerns and increase potential short-term releases of contamination to the environment. Also, a number

of implementation concerns are associated with the full containment alternative. Specialized equipment would be required, and verification of the successful implementation of the subsurface horizontal barriers would be difficult. Construction delays could result if the borehole spacing during construction is significantly different from that estimated during design. Estimated cost of the Full Containment alternative is higher than the cost of the Surface Barrier alternative. The Full Containment alternative was not retained for detailed analysis because of increased cost, implementation concerns, and the questionable increase in effectiveness.

Both in situ treatment alternatives were retained for detailed analysis. These alternatives are effective in achieving RAOs and protecting human health and the environment. As discussed previously, both ISG and ISV are established technologies. In addition, the INEEL has conducted a number of previous studies investigating the applicability of ISV and ISG for site-specific applications. Though not all technical issues have been fully resolved, available data indicate that both alternatives would be implementable.

The RTD alternative has been retained for detailed analysis. This alternative addresses specific stakeholder and State of Idaho issues in that it includes removing buried TRU waste from the site. In general, while the RTD alternative offers the highest degree of long-term protectiveness, it is also the most difficult to implement, imposes the highest degree of short-term risk to workers and the environment, and costs the most.

3.11 References

40 CFR 61 Subpart H, 2002, "National Emission Standards for Emissions of Radionuclides under the National Emission Standards for Hazardous Air Pollutants," *Code of Federal Regulations,* Office of the Federal Register, September 2002.

40 CFR 191, 2002, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," *Code of Federal Regulations*, Office of the Federal Register, February 2002.

40 CFR 300.430, 2002, "Remedial Investigation/Feasibility Study and Selection of Remedy," *Code of Federal Regulations,* Office of the Federal Register, November 2002.

42 USC § 6901 et seq., 1976, "Resource Conservation and Recovery Act (Solid Waste Disposal Act)," *United States Code,* October 21, 1976.

42 USC § 9601 et seq., 1980, "Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA/Superfund)," *United States Code,* December 11, 1980.

Armstrong, Aran T., Daniel A. Arrenholz, and Jerry R. Weidner, 2002, *Evaluation of In Situ Grouting for Operable Unit 7-13/14*, INEEL/EXT-01-00278, Rev. 0, Idaho National Engineering and Environmental Laboratory, CH2MHILL and North Wind Environmental for Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho.

Crouse, Phillip, 2002, *Liner and Final Cover Long-Term Performance Evaluation and Final Cover Life Cycle Expectation*, EDF-ER-281, Rev. 1, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

DOE, 1997, *Environmental Assessment and Plan for New Silt/Clay Source Development and Use at the INEEL,* DOE/EA-1083, U.S. Department of Energy.

DOE-ID, 2002, *Waste Acceptance Criteria for ICDF Landfill*, DOE/ID 10865, Rev. 2, U.S. Department of Energy Idaho Operations Office, Idaho Falls, Idaho.

DOE-ID, 1999, *Operable Unit 7-13/14, In Situ Grouting Treatability Study Work Plan*, DOE/ID-10690, Rev. 0, U.S. Department of Energy Idaho Operations Office, Idaho Falls, Idaho.

DOE-ID, 1994, *Record of Decision: Declaration for Pad A at the Radioactive Waste Management Complex Subsurface Disposal Area at the Idaho National Engineering Laboratory, Idaho Falls, Idaho*, Administrative Record No. 5632, U.S. Department of Energy Idaho Operations Office; U.S. Environmental Protection Agency, Region 10; Idaho Department of Health and Welfare.

DOE-ID, 1991, *Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory,* Administrative Record No. 1088-06-29-120, U.S. Department of Energy Operations Office; U.S. Environmental Protection Agency, Region 10; Idaho Department of Health and Welfare.

Earth Tech, 2002, "CALPUFF Modeling System," URL: http://www.calgrid.net/calpuff/calpuff1.htm, site last visited December 5, 2002.

EG&G, 1993, *Remedial Design/Remedial Action Scope of Work and Remedial Design Work Plan: Operable Unit OU 7-10 (Pit 9 Project Interim Action)*, EGG-ER-11055, Rev. 0., Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

EPA, 1996, *Technology Screening Guide for Radioactively Contaminated Sites*, EPA 402-R-96-017, Office of Air and Radiation, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1990, *Clean Air Act,* 42 USC, Chapter 85, "Air Pollution Prevention and Control," sec. 7401 et seq., U.S. Environmental Protection Agency.

EPA, 1988, *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*, OSWER Directive No. 9355.3-01, EPA/540/G-89/004, U.S. Environmental Protection Agency.

EPA, 1987, *Clean Water Act,* 33 USC, Chapter 26, "Water Pollution Prevention and Control," sec. 1251 et seq., U.S. Environmental Protection Agency.

IDAPA 58.01.01, 1994, "Idaho Water Quality Standards," Idaho Administrative Procedures Act, Idaho Department of Environmental Quality, May 1, 1994.

Khire, Miland V., Craig H. Benson, and Peter J. Bosscher, 2000, "Capillary Barriers: Design Variables and Water Balance," Vol. 126, Issue 8, pp. 695-708, *Journal of Geotechnical and Geoenvironmental Engineering*, AIP Publishing Center, Melville, New York.

Loomis, Guy G., 2001, *Preconceptual Design Features for Using Bridge Crane Deployed In Situ Grouting for In-Place Disposal of Buried TRU Waste at the INEEL SDA*, EDF-3101, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

Loomis, Guy G., Christopher M. Miller, and Stephen W. Prewett, 1997, *Mixed Waste Salt Encapsulation Using Polysiloxane—Final Report*, INEEL/EXT-97-01234, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

Loomis, Guy G., Andrew P. Zdinak, and Carolyn W. Bishop, 1997, *Innovative Subsurface Stabilization Project—Final Repotr (Revision 1)*, INEL-96/0439, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

Miller, Eric C., and Mark D. Varvel, 2001, *Reconstructing Past Disposal of 743 Series Waste in the Subsurface Disposal Area for Operable Unit 7-08, Organic Contamination in the Vadose Zone*, INEEL/EXT-01-00034, Rev. 0, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

Spence, R. D., M. W. Burgess, V. V. Fedorov, and D. J. Downing, 1999, *Cementitious Stabilization of Mixed Wastes With High Salt Loadings*, ORNL/TM-13725, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Thomas, T. N., and Russell L. Treat, 2002, *Evaluation of in Situ Vitrification for Operable Unit 7-13/14*, INEEL/EXT-01-00279, Rev. 0, Idaho National Engineering and Environmental Laboratory, CH2MHILL and Dade Moeller and Associates report for Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho.